FINAL REPORT VOLUME I

Federal Lands Alternative Transportation Systems Study

Candidate Vehicle Technologies

prepared for

Federal Highway Administration
Federal Transit Administration

prepared by

BRW Group, Inc.

August 2001

Candidate Vehicle Technologies for

Alternative Transportation Systems

U.S. Department of Transportation
Federal Highway Administration
Federal Transit Administration

Federal Lands Alternative Transportation Systems Study

Volume I

Final Report
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BRW
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This report documents alternative transportation needs in lands managed by the National Park Service, the U.S. Fish and Wildlife Service, and the Bureau of Land Management.

Volume I identifies and describes over 30 mass transit vehicle technologies in five categories -- (1)Bus, (2)Rail/Guided, (3)High Gradient, (4)Water, and (5)Snow -- with potential applicability for Federal lands. The descriptions include data on physical, operating, and economic characteristics, an assessment of the principal advantages and disadvantages, and information on typical applications of each technology.

Three attached appendices to this volume cover related topics in the areas of alternative fuels/propulsion systems, Intelligent Transportation Systems (ITS), and a list of vehicle manufacturers.

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Candidate Vehicle Technologies for Alternative Transportation Systems

Federal Lands Alternative Transportation Systems Study

D&M GROUP BRW
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Final Report
August 2001

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INTRODUCTION

This volume presents existing and emerging transit technologies appropriate for application on Federal lands. It identifies and describes a set of over 30 mass transit vehicle technologies in five vehicle categories – Bus, Rail/Guided, High Gradient, Water, and Snow - with potential applicability in Federal lands. The descriptions include data on physical, operating, and economic characteristics, an assessment of the principal advantages and disadvantages of each vehicle type with respect to several important criteria, and information on typical applications of each technology.

The purpose of this volume is to assist those involved in planning for transit systems in federally-managed lands to identify a short list of potentially-applicable transportation technologies to advance into more in-depth analysis and evaluation. This volume builds upon an earlier document titled *Alternative Transportation Modes Feasibility Study: Visitor Transportation System Alternatives* that was completed for the National Park Service in 1994. That report identified and described over 20 candidate transportation technologies with potential applicability to National Parks and federally-managed public lands.

Two technical appendices at the back of this volume cover related topics in the areas of alternative fuels and propulsion systems and Intelligent Transportation Systems (ITS). Appendix A – Alternative Fuels and Propulsion – provides a description of the types of fuel and propulsion systems that are alternatives to conventional gasoline and diesel engines for transportation. It discusses the advantages and disadvantages of each fuel/system type as well as the potential applicability to the range of vehicles. Appendix B – Intelligent Transportation Systems – provides an overview of how advanced information and communication technologies can improve transit system operations and transit customer convenience via real-time system tracking and management. These appendices provide an added dimension of information with relevance to the basic vehicle technology, and have a high degree of applicability in the National Parks and federally-managed public lands. A third appendix, Appendix C, provides a list of vehicle manufacturers and their web sites, organized by vehicle technology category.

Methodology

The approach to this transportation technology inventory update included the following activities.

- Review of the previous 1994 NPS report to reassess the suitability of vehicle technologies.
- Review of the inventory of existing alternative transportation systems in National Parks. (Buses and watercraft each account for about 45% of existing systems in National Parks.)
- Identification/nomination of other potentially applicable vehicle technologies from the Internet and other research as well as from general experience.
- Outreach to the transportation/transit industry at the APTA Annual Meeting in October 1999.
- Direct contact with numerous vehicle and related subsystems manufacturers via the Internet and other methods.
- Special studies regarding the potential relevance of the subject areas noted above for the Technical Appendices.
- Review of technical reports and data published by the Federal Transit Administration (FTA), the Transportation Research Board (TRB) and other industry journals.

Summary of Results

The results of the Volume I work can be summarized as follows. Eleven additional candidate vehicle technologies were added to 20 vehicle technologies from the original 1994 NPS report. (The original report contained 21 vehicle technologies, two of which were consolidated for this report.) Vehicle characteristics, cost data, and an assessment of vehicle advantages and disadvantages were updated for all vehicle technologies. A new category – Snow Transit – was added. A summary of changes by vehicle technology category is shown below.

- Buses – 5 new bus types added → total of 14 vehicle types
- Rail/Guided Transit – 3 new vehicle types added → total of 7 vehicle types
- High Gradient Transit – no changes in vehicle types → total of 4 vehicle types
- Waterborne Transit - 1 new boat type added → total of 4 boat types
- Snow Transit – New category with 2 new snow vehicle types

Important new bus and rail vehicle findings with direct relevance to National Parks and federally-managed public lands as compared to the 1994 study are listed below.

Buses

- Alternative fuels/low emission propulsion systems are now generally available for most types of buses.
- Low floor has become a more available option on a variety of buses as opposed to being a nearly custom option previously.
- Composite materials are reducing the curb (empty) weight of buses. Bus length and passenger capacity can therefore be increased without increasing the gross (loaded) weight.
- Intelligent Transportation Systems (ITS) technology has become more prevalent in transit systems management and control, and for customer information.

Rail Vehicles

- Availability of new design, self-propelled rail vehicles in the light rail/regional rail category has improved considerably since the 1994 NPS report.

The remainder of this volume provides more detailed information on the characteristics and applicability of the various alternative transportation technologies.

OVERVIEW OF CANDIDATE TECHNOLOGIES

This section provides an introduction to the candidate vehicle technologies for alternative transportation systems in Federal lands. Thirty-one vehicle technologies or vehicle types have been identified in the following five major categories. The vehicle technologies are listed by category on Table 1. Vehicle technologies that have been added since the original 1994 NPS report are so noted.

Table 1
Candidate Transportation Technologies

Item No.	Category	Technology
1	Bus Transit	Tourist Trams
2		Vans and Van Conversions
3		School Buses
4		Small Transit Buses
5		Historic Trolley Replicas*
6		Standard Transit Buses
7		Airport Apron Buses*
8		Articulated Transit Buses
9		Bi- Articulated Buses*
10		Buses with Trailers*
11		Low Floor Transit Buses
12		Motor Coaches
13		Double Decker Buses
14		Electric Trolleybuses*
15	Rail / Guided Transit	Historic Trolleys*
16		Narrow Gauge Rail*
17		Moving Cableway Shuttle Transit*
18		People Movers
19		Monorail
20		Light Rail Transit (LRT)
21		Conventional Passenger Rail
22	High Gradient Transit	Cog Railways
23		Funiculars
24		Aerial Tramways
25		Gondolas
26	Waterborne Transit	Pontoons and Skiffs*
27		Mono Hull Vessels
28		Catamarans
29		Hydrofoils
30	Snow Transit*	Snow Coaches*
31		Snow Buses*

* Vehicle technologies added since 1994 NPS Report.

Bus Transit – These rubber tired vehicles are manually operated and typically propelled by conventional internal combustion engines (gasoline or diesel) or alternative fuels such as compressed natural gas. Buses can use existing or improved public roads to or within parks/public lands. Most new alternative transportation systems for the National Parks and federally-managed public lands will likely be based on buses. There are 14 types of bus vehicles included in this category.

Rail / Guided Transit – These are vehicle systems that require tracking or guidance elements such as railroad track, cable, or guidance system on a structure. This category includes light rail, conventional passenger rail, "people mover" systems, and others. Some of these systems can be automated. Seven vehicle technologies are included in this category.

High Gradient Transit – These are vehicle technologies specially designed for steep mountainous terrain or other difficult settings. This category includes cog and cable–driven railways and cable suspended systems. Four vehicle technologies are included in this category.

Waterborne Transit – Four types of group watercraft are included in this category from shallow bottomed skiffs to hydrofoils.

Group Snow Transit – This is a new category with two entries –Snow Coaches and Snow Buses.

An introductory page provides an overview of each category. For each specific vehicle technology or vehicle type within the category there is a two-page layout that describes the technology and its typical application, its advantages and disadvantages with respect to a common checklist of criteria, and vehicle characteristics with data covering physical, operating, and economic aspects of the technology. Pictures of various models of that vehicle technology are presented on the facing page.

Table 2 provides an overview of the potential applicability of each of the bus and rail technologies to the National Parks and federally-managed public lands. (High gradient, water, and snow technologies are special cases and are not included on the table.) This table shows how each vehicle technology might accommodate various types of travel demand and the corresponding range of person-carrying capacities.

Four major types of trips for federally-managed lands are shown on Table 2 – two for getting to/from the park/public land and two for travel within the park/public land. The "to/from" category covers both short trips (<5 miles) that might connect the park/public land to a nearby gateway community and long trips (>5 miles) that might connect the park to a distant metropolitan area. All of the bus technologies have potential applicability for the short "to/from" trip except visitor trams, airport apron buses, and motor coaches. The trams/apron buses are not well suited for higher speeds and mixing with other traffic on the public roadways. These vehicles typically have very low floors and a larger width than most bus transit vehicles. The motor coach is the only bus type specifically designed for longer distance travel. On the rail side, most of the technologies are also suited to the shorter "to/from" trip, although People Mover and Cable Shuttle might be limited to about 2 miles. Conventional passenger rail vehicles, some of which may be self-propelled, are better suited to the longer distance trip.

For travel within the park, two types of trips have been noted on Table 2. Shuttle trips are shorter point-to-point connecting trips that might link two major activity areas such as a parking facility with a visitor center. Tour trips, on the other hand, connect a sequence of stops or visitor destinations and might resemble a traditional scheduled, fixed route transit service with frequent on and off activity along the way. For both the bus and rail/guided categories, nearly all technologies have applicability to the shuttle type of trip. On the longer tour type of trip it appears that the smaller end of the bus spectrum has the most potential applicability (buses with trailers are based on small transit buses). The larger bus types are generally thought to have characteristics that make them less attractive in this use than the smaller vehicles – weight and turning radius - for the tour type of service within a park or public land.

Table 2
Applicability of Bus and Fixed Guideway Transit Technologies
to National Park/Public Lands Travel Needs

Vehicle Type	Trip Type*				Demand Range* (Passengers per Hour)			Remarks*
	To/From Park		Within Park					
	Short (<5 mi)	Long (>5 mi)	Shuttle	Tours	10's	100's	1000's	
Bus Transit								
Visitor Trams			X	X		X		Excl., Pv.
Vans & Van Conversions	X		X	X	X	(x)		
School Buses	X		X	X		X		
Small Transit Buses	X		X	X		X		
Trolley Bus Replicas	X		X	X		X		
Standard Transit Buses	X		X			X		
Airport Apron Buses			X			X	(x)	Wt., Excl., Pv.
Articulated Buses	X		X			X	(x)	Wt.
Bi-Articulated Buses	X		X			X	(x)	Wt.
Buses with Trailers	X		X	X		X	(x)	Excl.
Low-Floor Buses	See individual transit buses.							Wt., Pv.
Motor Coaches		X		(x)		X		Wt.
Double Decker Buses	See transit buses or motor coaches							Wt., Clr
Electric Trolleybuses	X		X			X		Wt., Elec.
Rail/Guided Transit								
Historic Trolleys	X		X	(x)		X		Excl., Elec.
Narrow Gauge Rail	X		X	(x)		X		Excl.
Moving Cable Shuttle Transit	X		X				X	Elev.
People Mover	X		X				X	Elev., Elec. Excl.
Monorail	X		X				X	Elev., Elec.
Light Rail Transit	X		X				X	Elec.
Conventional Passenger Rail		X				X	X	Excl.
Self Propelled Diesel Transit	X	X	X				X	Excl.

*Notes:
- Clr. = high overhead clearance required
- Elec. = high voltage electricity required.
- Elev. = elevated structure required.
- Excl. = exclusive or partially exclusive at-grade right-of-way desired.
- Pv. = pavement surface must be very smooth, even, and level to accommodate low ground clearance.
- Wt. = heavy axle loadings; structurally sound pavement design required.
- X = primary trip type or demand range for this vehicle
- (x) = secondary trip type or demand range for this vehicle

The 1994 version of this report contained a category of information for operating costs. This version does not provide that information because there is so much variability in the typical ranges for each vehicle technology. For example, the universally-used standard transit bus has an hourly operating cost that can range from as low as $40 per hour, upward to $100 per hour, depending on average local wage rates, operating practices (full or part-time drivers); the presence/absence of unions, the bus route design, and background traffic conditions. Operating cost information for other, less-universal technologies can be even more variable. It is therefore recommended that this report be used to select viable candidate technologies based upon capacity and capital costs, and that further, localized information be gathered to estimate operating costs.

The purpose of this discussion has been to provide an overview of potential applicability of the various technologies to the park/public lands environments. The selection of a particular vehicle system technology will require a site-specific study of visitor travel demand and park/public land facilities and conditions. Other transportation system elements such as vehicle maintenance and storage facilities, fueling infrastructure, passenger facilities for waiting/boarding, and customer information will also need to be considered in the development of a plan for an alternative transportation system.

In general, the selected Alternative Transportation System for a National Park or related federally-managed lands will need to be capable of serving the level and type of anticipated visitation, be compatible with the character of the visitor experience, and be sensitive to the natural and cultural environment of the public lands.

Table 3 contains a list of relevant abbreviations and acronyms used throughout this report.

Table 3
Abbreviations and Acronyms Used in this Report

Abbreviation or Acronym	Definition
AC	Alternating Current
ADA	Americans with Disabilities Act (1990)
AGT	Automated Guideway Transit
APTA	American Public Transportation Association
Artic.	Articulated
ATS	Alternative Transportation Systems
BLM	Bureau of Land Management
BRT	Bus Rapid Transit
CDL	Commercial Drivers License
CNG	Compressed Natural Gas
DC	Direct Current
dd	double deck
DMU	Diesel Multiple Unit
FGT	Fixed Guideway Transit
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
ft.	foot or feet
FWS	(U.S.) Fish and Wildlife Service
gal	Gallon
ICT	Inter-City Train
ITS	Intelligent Transportation System(s)
kW	Kilowatt
kwh	kilowatt hour
lbs.	Pounds
LNG	Liquefied Natural Gas
LRT	Light Rail Transit
mpg	miles per gallon
mph	miles per hour
NPS	National Park Service
sl	single level
sq. ft.	square feet
std.	Standard
TRB	Transportation Research Board
V	Volts
veh	Vehicle

BUS TRANSIT

INTRODUCTION TO BUS / RUBBER TIRED TRANSIT

Bus transit is by far the most common type of public transportation in the world today. Bus systems of some form exist in virtually every urban area in the country and in a number of national park units. Buses can operate on fixed routes according to published schedules, or may be dispatched to pick up passengers on a demand-responsive basis.

The general category of bus transit is comprised of manually-operated rubber-tired vehicles. Nearly all types of bus transit are designed to operate in mixed traffic, on ordinary roadways. All except one (electric trolleybuses) are self-propelled by an on-board engine and power source.

Buses have three major advantages that account for their predominance as a transit technology.

- First, they are the least expensive of all land-based technologies. They do not require a large investment in construction and maintenance of new infrastructure since they can use existing roadways.
- Second, they offer unequaled routing flexibility. Because they are not tied to a fixed guideway, they can easily be re-routed to respond to varying demand and can cover broad areas of demand.
- Third, buses can serve a very wide range of passenger demand levels by using small to very large vehicles. Because of the high number of suppliers and the general availability in the market, it is easy to rent or lease vehicles of all sizes, to adapt to changing demand.

Buses also have a number of disadvantages that make them unsuitable for some uses:

- The labor cost per passenger carried is high. (Labor wages and benefits can easily be twice the cost of bus capital costs on an annualized basis.)
- Most large buses are currently powered by diesel engines, noise levels and the emission of pollutants may be objectionable in remote, natural settings, although this is rapidly changing. A variety of alternative fuel technologies, including compressed natural gas, liquefied natural gas, and propane, are available at somewhat higher capital and operating costs.
- Locations with water travel, high grades, or with very tight operating tolerances may preclude use of buses.

Bus transit encompasses a wide variety of vehicles, ranging from converted vans to double-deck and articulated (jointed) transit buses. School buses, motor coaches, and power unit/trailer combinations represent variations from the traditional urban transit vehicle. Other technological innovations include automatic vehicle location systems, automated demand-responsive dispatching, transit operations software, electronic ticketing, and automated fare payment. Although buses typically operate in mixed traffic, several cities have built exclusive busways or bus lanes that exclude or restrict other vehicles. Similar types of facilities exist at Zion National Park and Cape Cod National Seashore. On other facilities, buses can provide faster service by adding lanes to bypass congestion.

For purposes of this section, the terms “low,” “moderate,” and “high” are used relative to bus transit passenger volumes to describe their applicability in serving passengers per hour. From the introduction for this report (refer back to Table 2) bus technologies are listed as applicable in the demand range of tens, hundreds or thousands of passengers per hour. Low refers to demand in the tens to several hundreds of passengers per hour; moderate refers to hundreds of passengers per hour; high refers to the upper end of hundreds of passengers per hour and into the few thousands of passengers per hour.

Currently, buses and other rubber-tired vehicles are the most common form of land-based transit service operating in national park units. Nearly all buses, excepting older used models, have equipment such as wheelchair lifts that make them accessible to all populations and make them compliant with the Americans with Disabilities Act of 1990 (ADA). Standard bus technology allows for high to moderately high levels of interaction between the operator and passengers. Operators are typically able to provide some degree of passenger assistance.

BUS TRANSIT

Tourist Trams

TOURIST TRAMS

Other Names: Small Trams, Visitor Trams

Description
These specialized units use a powered tractor to pull one or more passenger trailer units. To operate effectively, a controlled environment such as an exclusive paved road is required. Various designs are available, including vehicles modeled after trains and other unique carnival vehicles. The powered tractors may or may not also have passenger capacity. The vehicles are in a size range similar to the range between golf carts and standard passenger vans. These vehicles are effective for moderate to high passenger volumes and do especially well where frequent loading and unloading of large groups is required.

Characteristic	Advantages	Disadvantages
Maneuverability	- Maneuverable on narrow roads with tight corners, even with multiple trailers. - Can operate with low overhead clearances.	- Require a separate (exclusive) roadway. - Slow maximum operating speed relative to other vehicles. - Cannot reverse.
Durability	- See cost.	- Shorter life span than transit buses. - Most models (gas engines) not suitable for engine rebuilds to extend vehicle life.
Operator Availability	- Ready supply of operators.	- Requires special driver training for safety.
Noise	- Smaller engines in these vehicles make noise comparable to the passenger auto.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Moderate fuel type availability.	- No significant disadvantages.
Cost	- Low initial/capital cost relative to transit buses of similar capacity. - Operating cost low relative to the number of passengers that can be served.	- More frequent replacement required than for transit buses.
Vehicle, Parts, Service Availability	- Ready supply of mechanics. - ADA equipment available.	- Limited number of suppliers. - Used models and lease/rent/charter opportunities less available than other vehicles. - More mechanically complex than std. Buses.
Compatibility with Federally- Managed Sites	- Small size and car-like appearance may be more compatible in remote settings. - Appearance has higher novelty/visitor appeal than similar-capacity buses.	- Need paved road for adequate traction. - Not appropriate for steep terrain.
Vehicle Features	- Parallel boarding/alighting is very efficient. - Open air versions common and increase viewing opportunities. - Designed for frequent stops.	- More mechanically complex than std. Buses. - Not suitable for traditional fare collection.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	10 to 20 feet (power unit) 20 to 25 feet (trailer unit)
Width:	5 to 8 feet
Height:	6 to 10 feet
Weight:	5,000 to 10,000 pounds (per unit)
Power Source:	Gasoline, diesel, propane, electric
Low Floor:	Generally Available

Economic Data	
Vehicle Cost:	\$40,000 to \$100,000 (power unit) \$15,000 to \$70,000 (trailer unit)
Vehicle Life:	5 to 10 years 75,000 to 100,000 miles

Operating Data	
Maximum Operating Speed:	25 mph
Maximum Grade:	10%
Turn Radius:	20 to 30 feet
Passengers per unit (Up to 4 units total)	
Seated:	20 to 35
Standees:	0 (not typical)
Total:	20 to 35
Fuel Consumption:	3 to 5 mpg

Notes
None.

BUS TRANSIT

Vans and Van Conversions

VANS AND VAN CONVERSIONS

Other Names: Body On Chassis, Cut Away, Minibus

Description

Vans and converted vans are a versatile form of bus transit used to support small- to medium-sized groups. They are commonly used for short-haul transportation around airports and other activity centers, and for longer-distance travel to resorts from urban areas. They are also commonly used to provide complementary paratransit service to elderly and disabled persons who cannot access standard transit services. Most versions of these vehicles are best suited to point-to-point travel with a minimum amount of passenger boarding and alighting. These vehicles typically have only one passenger door, often have lower ceilings, and more limited interior space than transit buses.

Characteristic	Advantages	Disadvantages
Maneuverability	- Maneuverable on narrow roads with tight corners. - Can operate with low overhead clearance.	- No significant disadvantages.
Durability	- See cost.	- Shorter life span than transit buses. - Most models (gas engines) not suitable for engine rebuilds to extend vehicle life.
Operator Availability	- Ready supply of operators.	- See cost.
Noise	- Gas versions and smaller engine size make noise comparable to passenger auto.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Wide fuel type availability.	- No significant disadvantages.
Cost	- Low initial/capital cost relative to transit buses.	- Operating (labor) cost high relative to number of passengers served.
Vehicle, Parts, Service Availability	- Ready supply of manufacturers & mechanics. - Ready supply of lease/rent/charter opportunities.	- No significant disadvantages.
Compatibility with Federally-Managed Sites	- Small size and car-like appearance may be more compatible in remote settings. - Low axle weights reduce need for road upgrades.	- With moderate to heavy passenger loads, many vehicles required.
Vehicle Features	- Variety of seating arrangements. - Ready availability of equipment for ADA service.	- Typically only a single door for passenger boarding/alighting. - Low floor versions not typically available. - Not designed for sustained high-speed operation.
Other	- Smaller vehicles in this category may not require commercial driver's license (CDL).	- No significant disadvantages.

Physical Data	
Length:	15 to 26 feet
Width:	7 to 8 feet
Height:	6 to 10 feet
Weight:	9,000 to 12,000 pounds
Power Source:	Gasoline, diesel, methanol, compressed natural gas, liquefied natural gas, propane, battery
Low Floor:	Not generally available

Economic Data	
Vehicle Cost:	$25,000 to $50,000
Vehicle Life:	5 to 10 years 100,000 to 200,000 miles

Operating Data	
Maximum Operating Speed:	60 mph
Maximum Grade:	15%
Turn Radius:	20 to 25 feet
Passengers	
Seated:	8 to 25
Standees:	0 to 5
Total:	8 to 30
Fuel Consumption:	8 to 10 mpg

Notes

Battery versions have limited range.

BUS TRANSIT

School Buses

SCHOOL BUSES

Other Names: None

Description
Buses based on school bus design offer a low-cost option to transit buses and typically have more capacity than vans and van conversions. School buses are often an effective solution to seasonal visitor travel. Where private contractors provide school transportation, idle school buses may be available for lease during the summer. Being designed for school children, these buses provide less comfortable seating than transit buses. School bus seat modifications can also be made quite easily for easier access and more room.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- No significant disadvantages.
Durability	- Highly durable interiors.	- Shorter life span than transit buses. - Some models (gas engines) not suitable for engine rebuilds to extend vehicle life.
Operator Availability	- Ready supply of operators.	- No significant disadvantages.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Typically available in gasoline or diesel versions.	- Less widely available with alternate fuels such as CNG, LNG, or propane than other vehicles.
Cost	- Low initial/capital cost relative to transit buses.	- No significant disadvantages.
Vehicle, Parts, Service Availability	- Ready supply of manufacturers & mechanics. - Ready supply of lease/rent/charter opportunities, especially in the summer.	- No significant disadvantages.
Compatibility with Federally-Managed Sites	- Low axle weights reduce need for road upgrades.	- No significant disadvantages.
Vehicle Features	- Designed for moderately frequent stops. - Variety of sizes available. - Ideal for transporting children to recreational destinations.	- Typically only a single door for passenger boarding/alighting. - Low floor versions not typically available. - Not designed for sustained high-speed operation. - Small windows limit visibility. - Less comfortable seating, especially for adults, than transit buses. - Less sophisticated suspension than transit bus provides a rougher ride.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	17 to 38 feet
Width:	8 feet
Height:	9 to 11 feet
Weight:	10,000 to 30,000 pounds
Power Source:	Gasoline, diesel, natural gas.
Low Floor:	Not generally available

Operating Data	
Maximum Operating Speed:	60 mph
Maximum Grade:	15%
Turn Radius:	25 to 39 feet
Passengers	
Seated:	20 to 45
Standees:	0 (standees not typical)
Total:	20 to 45
Fuel Consumption:	4 to 10 mpg

Economic Data	
Vehicle Cost:	$70,000 to $120,000
Vehicle Life:	8 to 10 years
	300,000 to 500,000 miles

Notes
None.

BUS TRANSIT

Small Transit Buses

SMALL TRANSIT BUSES

Other Names: Mid Sized Bus

Description
These buses are used in urban areas with lower ridership levels where standard transit buses are not justified. They offer better maneuverability than standard transit buses and somewhat lower initial costs. On a per-passenger basis, these models are generally more expensive than larger buses or school buses. These buses are durable, having been designed for repetitive start and stop operation. These buses offer all the advantages of their larger counterparts in accommodating on and off movements of passengers and providing room for standees.

Characteristic	Advantages	Disadvantages
Maneuverability	- Maneuverable on narrow roads with tight corners	- No significant disadvantages.
Durability	- Long life span of 12 to 15 years. - Most models have diesel engines that are suitable for rebuilds to extend vehicle life.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- See cost.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Wide fuel type availability.	- No significant disadvantages.
Cost	- Lower initial/capital cost than standard transit buses.	- High initial/capital cost compared to school buses and vans - Operating (labor) cost moderately high relative to the number of passengers served.
Vehicle, Parts, Service Availability	- Ready supply of manufacturers & mechanics. - Ready supply of lease/rent/charter opportunities.	- No significant disadvantages.
Compatibility with Federally-Managed Sites	- Lower axle weights reduce need for road upgrades.	- With moderate to heavy passenger loads, many vehicles required. - Urban appearance may be less desirable in remote settings.
Vehicle Features	- Variety of seating arrangements. - Ready availability of equipment for ADA service. - Designed for frequent stops. - Large windows relative to vans and school buses afford better passenger viewing. - Multiple doors for easy boarding/alighting.	- Not designed for sustained high-speed operation.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	25 to 30 feet
Width:	7.5 to 8.5 feet
Height:	9 to 11 feet
Weight:	15,000 to 37,000 pounds
Rear Axle Weight:	10,000 to 25,000 pounds
Power Source:	Diesel, methanol, liquefied natural gas, compressed natural gas, battery.
Low Floor:	Generally Available
Economic Data	
Vehicle Cost: (Average):	$150,000 to $225,000 ($211,000)
Vehicle Life:	12 to 15 years 500,000 to 1,000,000 miles

Operating Data	
Maximum Operating Speed:	60 mph
Maximum Grade:	15%
Turn Radius:	24 to 30 feet
Passengers	
Seated:	20 to 35
Standees:	0 to 10
Total:	20 to 45
Fuel Consumption:	4 to 7 mpg

Notes
Battery versions have limited range.
Low floor versions of this vehicle are available.

BUS TRANSIT

Historic Trolley Replicas

HISTORIC TROLLEY REPLICAS

Other Names: Rubber Tire Trolleys

Description

Historic trolley replica vehicles are a variation, typically of a small transit bus, although some versions based on standard transit buses are available. Historic trolley replicas are used in areas with lower ridership levels. On a per-passenger basis, these vehicles are generally more expensive than larger buses or school buses. Their chief advantage is that they are easily identifiable and distinctive. This can be an advantage if other transit systems or routes are operating simultaneously. Because they are based on transit buses, historic trolleys are relatively durable.

Characteristic	Advantages	Disadvantages
Maneuverability	- Maneuverable on narrow roads and tight corners.	- No significant disadvantages.
Durability	- Long life span of 10 to 15 years. - Models with diesel engines are suitable for rebuilds to extend vehicle life.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- See cost.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Wide fuel type availability.	- No significant disadvantages.
Cost	- No significant advantages.	- High initial/capital cost. - Operating (labor) cost moderately high relative to the number of passengers that can be served.
Vehicle, Parts, Service Availability	- Ready supply of mechanics. - Moderate supply of lease/rent/charter opportunities.	- Fewer suppliers than for transit buses.
Compatibility with Federally-Managed Sites	- Lower axle weights reduce the need for road upgrades. - Appearance has higher novelty/visitor appeal than transit buses of the same size.	- With moderate to heavy passenger loads, many vehicles are required.
Vehicle Features	- Variety of seating arrangements. - Ready availability of ADA equipment. - Designed for frequent stops. - Open air versions available. - Large windows and open-air versions increase viewing opportunities.	- Not designed for high-speed operation.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	25 to 30 feet
Width:	7.5 to 8.5 feet
Height:	9 to 11 feet
Weight:	20,000 to 30,000 pounds
Rear Axle Weight:	19,000 pounds
Power Source:	Diesel, methanol, liquefied natural gas, compressed gas
Low Floor:	Not generally available

Operating Data	
Maximum Operating Speed:	60 mph
Maximum Grade:	15%
Turn Radius:	24 to 30 feet
Passengers	
Seated:	20 to 35
Standees:	0 to 10
Total:	20 to 45
Fuel Consumption:	4 to 7 mpg

Economic Data	
Vehicle Cost:	$200,000 to $275,000
(Average):	($250,000)
Vehicle Life:	10 to 15 years

Notes

None.

BUS TRANSIT

Standard Transit Buses

STANDARD TRANSIT BUSES

Other Names: Conventional Transit Buses, Forty-footers

Description

Standard transit buses are useful in areas of moderate to high-volume, short-to-medium distance travel. The design of these buses provides for efficient loading and unloading in areas with frequent stops and complex visitor travel patterns. Typical designs provide grab bars for numerous standees. Standard transit buses require 11- to 12-foot lane widths for safe operation. The floor of standard transit buses is typically 25 to 30 inches above the pavement, although low floor buses are now available.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Require 11- to 12-foot wide lanes for safe operation.
Durability	- Long life span of 12 to 15 years. - Many models have diesel engines that are suitable for rebuilds to extend vehicle life.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- No significant disadvantages.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Wide fuel type availability.	- No significant disadvantages.
Cost	- Operating cost moderate relative to number of passengers that can be served.	- High initial/capital cost. - May not be cost effective for low to moderate passenger loads.
Vehicle, Parts, Service Availability	- Ready supply of manufacturers & mechanics. - Ready supply of lease/rent/charter opportunities. - Active bus rebuilding and used bus market.	- No significant disadvantages.
Compatibility with Federally-Managed Sites	- No significant advantages.	- Large size and urban appearance may be less desirable in remote settings. - Large size not suited to some narrow roads. - High axle loads require structurally sound roads.
Vehicle Features	- Variety of seating arrangements. - Ready availability of equipment for ADA service. - Designed for frequent stops. - Large windows relative to vans and school buses afford better passenger viewing. - Multiple doors for easy boarding/alighting.	- Not designed for sustained high-speed operation. - Not as comfortable as tour bus for long-distance travel.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	35 to 42 feet
Width:	8.0 to 8.5 feet
Height:	10 to 12 feet
Weight:	30,000 to 45,000 pounds
Rear Axle Weight:	26,000 pounds
Power Source:	Diesel, methanol, liquefied natural gas, compressed natural gas, battery, and hybrid.
Low Floor:	Generally Available

Economic Data	
Vehicle Cost:	\$200,000 to \$300,000
(Average):	(\$291,000)
Vehicle Life:	12 to 15 years 500,000 to 1,000,000 miles

Operating Data	
Maximum Operating Speed:	60 mph
Maximum Grade:	15%
Turn Radius:	28 to 40 feet
Passengers	
Seated:	35 to 48
Standees:	15 to 30
Total:	65 to 78
Fuel Consumption:	3 to 5 mpg

Notes

Battery versions have limited range.
Low floor versions of this vehicle are available.
Electric (trolleybus) versions of this vehicle available.

BUS TRANSIT

Airport Apron Buses

AIRPORT APRON BUSES

Other Names: Airport Shuttle Bus, Apron Bus

Description
These buses are useful for moderate to high passenger volume and short distance travel. The multiple wide doors and low floor design of these buses offer very efficient loading and unloading in areas with frequent stops and high volumes of simultaneous boarding and alighting. Like low floor transit buses, these buses have fewer seats and devote most of their floor area to standing passengers. Unlike low floor buses, most of these buses require extra-wide and extra-smooth paved roadways. Originally designed to carry passengers between airport concourses or between airplanes and concourses, these buses are now being used in shuttle applications. Some versions of this vehicle have driver cabins at both ends for efficient reverse operation.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Require 11- to 15- foot lanes to operate safely.
Durability	- No significant advantages.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special driver training for safety.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Moderate fuel type availability.	- No significant disadvantages.
Cost	- Operating cost moderate to low relative to the number of passengers that can be served.	- High initial/capital cost.
Vehicle, Parts, Service Availability	- No significant advantages.	- Limited number of suppliers, especially domestically. - Used models and lease/rent/charter opportunities less available than for other vehicles.
Compatibility with Federally-Managed Sites	- Unusual appearance may have higher novelty/visitor appeal than similar-capacity articulated buses.	- Large size and modern appearance may be less desirable in remote settings. - Requires smooth paved surface due to low clearance. - Unable to operate on moderate to steep grades. - Low clearance reduces max operating speed. - High axle loads require structurally sound roads
Vehicle Features	- Large windows increase viewing opportunities - Designed for frequent stops. - Provide similar capacity to articulated buses, but are shorter in overall vehicle length. - Multiple doors for easy boarding/alighting.	- Not designed for high-speed operation. - Not designed for long-distance travel. - May require vehicle maintenance facilities sized for vehicles wider than standard transit buses. - Not suitable for traditional fare collection.
Other	- No significant advantages	- No significant disadvantages

Physical Data	
Length:	32 to 47 feet
Width:	8 to 12 feet
Height:	9 to 10 feet
Weight:	25,000 to 52,000 pounds
Power Source:	Gas, diesel, compressed natural gas.
Low Floor:	Essential to this bus type.

Operating Data	
Maximum Operating Speed:	35 mph
Maximum Grade:	5% to 10%
Turn Radius:	35 to 60 feet
Passengers	
Seated:	5 to 16
Standees:	20 to 132
Total:	40 to 148
Fuel Consumption:	4 to 7 mpg

Economic Data	
Vehicle Cost:	$300,000 to $400,000
Vehicle Life:	10 to 15 years

Notes
None.

BUS TRANSIT

Articulated Transit Buses

ARTICULATED TRANSIT BUSES

Other Names: Artics, Mono-articulated Buses

Description
An articulated bus is a 55-60 foot transit bus that includes a trailer joined to the main vehicle by a special joint or articulation. These buses can carry large numbers of passengers and operate on most standard urban streets. They are most useful in areas of high demand. Most models have multiple doors for easy boarding and alighting. First introduced to the United States in the 1970's these buses have been very successful in serving heavily traveled corridors. Bi-articulated buses are now available in Latin America and Europe and while their appearance is similar, they have different operating characteristics. See the next page for more on bi-articulated buses.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Require 11- to 12-foot wide lanes for safe operation.
Durability	- Long life span of 10 to 15 years. - Many models have diesel engines that are suitable for rebuilds to extend vehicle life.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- Requires special driver training for safety.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Wide fuel type availability.	- No significant disadvantages.
Cost	- Operating cost low relative to the number of passengers that can be served.	- High initial/capital cost. - May not be effective for low or moderate passenger loads or seasonal use.
Vehicle, Parts, Service Availability	- Ready supply of mechanics. - Active bus rebuilding market.	- Fewer suppliers, especially domestically, of these vehicles. - Used models and lease/rent/charter opportunities less available than other vehicles
Compatibility with Federally-Managed Sites	- Fewer vehicles needed for high ridership.	- Large size and urban appearance may be less desirable in remote settings. - Large size not suited to some narrow roads. - High axle loads require structurally sound roads.
Vehicle Features	- Variety of seating arrangements. - Ready availability of equipment for ADA service. - Suitable for frequent stops. - Large windows afford better passenger viewing opportunities. - Multiple doors for easy boarding/alighting.	- Not designed for sustained high-speed operation. - More complex mechanically than standard buses. - Requires longer curb area for boarding/alighting. - Requires large service & maintenance area.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	56 to 60 feet
Width:	8.0 to 9.0 feet
Height:	10 to 12 feet
Weight:	50,000 to 66,000 pounds
Mid Axle Weight:	26,000 pounds
Rear Axle Weight:	26,000 pounds
Power Source:	Diesel, methanol, liquefied natural gas, compressed natural gas.
Low Floor:	Generally Available

Economic Data	
Vehicle Cost:	\$350,000 to \$450,000
(Average):	(\$392,000)
Vehicle Life:	10 to 15 years 500,000 to 1,000,000 miles

Operating Data	
Maximum Operating Speed:	55 mph
Maximum Grade:	10%
Turn Radius:	40 to 50 feet
Passengers	
Seated:	50 to 70
Standees:	20 to 50
Total:	90 to 120
Fuel Consumption:	2 to 4 mpg

Notes
Low floor versions of this vehicle available.
Electric (trolleybus) versions of this vehicle available.

BUS TRANSIT

Bi-Articulated Buses

BI-ARTICULATED BUSES

Other Names: Bi-Artics, Double Articulated Buses

Description

These buses are designed to operate in environments with heavy to very heavy passenger volumes, on medium-distance trips. These vehicles have three to four doors along their length for efficient passenger boarding and alighting. These buses were originally designed as a low-cost alternative to light rail (a.k.a. street trams or electric trolleys) for use with stations in a transit system known as Bus Rapid Transit (BRT). They are currently in use in several cities in Brazil. Because of their size, they typically require 11- to 12-foot lane widths and priority treatment within or complete separation from other vehicular traffic flows.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Require at minimum priority treatment within existing traffic, but complete separation preferred. - Require 11- to 12-foot wide lanes.
Durability	- Long life span of 10 to 15 years. - Models with diesel engines are suitable for rebuilds to extend vehicle life.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special driver training for safety.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Current models are diesel only.	- Alternate fuel versions untested at this time.
Cost	- Operating cost very low relative to the number of passengers that can be served.	- High initial/capital cost. - Likely only cost effective with high to very high passenger volumes.
Vehicle, Parts, Service Availability	- Ready supply of mechanics.	- Few suppliers, none domestic, of these vehicles. - Very few if any used vehicles or lease/rent/charter opportunities.
Compatibility with Federally-Managed Sites	- Fewer vehicles needed for high or very high ridership. - May provide equivalent capacity without the overhead electric wires common to light rail.	- Large size and urban appearance may be less desirable in remote settings. - Large size not suited to narrow roads. - High axle loads require structurally sound roads
Vehicle Features	- Variety of seating arrangements. - Large windows afford better passenger viewing opportunities than vans or school buses. - Multiple doors for easy boarding/alighting.	- Not designed for sustained high-speed operation. - More complex mechanically than std. buses. - Not suitable for traditional fare collection. - Requires longer curb area for boarding/alighting - Requires large service and maintenance area.
Other	- No significant advantages	- No significant disadvantages

Physical Data	
Length:	80 feet
Width:	8 to 9 feet
Height:	10 to 12 feet
Weight:	67,000 to 87,000 pounds
Mid Axle Weight:	26,000 pounds
Rear Axle Weight:	26,000 pounds
Power Source:	Diesel
Low Floor:	Not generally available

Operating Data	
Maximum Operating Speed:	50 mph
Maximum Grade:	10%
Turn Radius:	40-50 feet
Passengers	
Seated:	50 to 90
Standees:	60 to 150
Total:	150 to 200
Fuel Consumption:	2-4 mpg

Economic Data	
Vehicle Cost:	\$450,000 to \$600,000
Vehicle Life:	10 to 15 years 500,000 to 1,000,000 miles

Notes

BRT System including exclusive lanes and stations costs \$300,000 to \$3.0 Million per mile to implement.

BUS TRANSIT

Buses with Trailers

BUSES WITH TRAILERS

Other Names: Modular Transit, LargeTrams, Bus Trains

Description

These units use a powered lead vehicle to pull one or more un-powered passenger trailer units. To operate effectively, a controlled environment, such as an exclusive paved road, is desired. Most designs are variants of small transit buses, although a version based on a standard transit bus has recently become available. Generally, both the power units and the trailing units provide passenger capacity. These vehicles are effective for moderate to high passenger volumes. These vehicles are less maneuverable than the smaller trams, but more maneuverable than articulated buses. They provide the flexibility to respond to seasonal visitor volumes.

Characteristic	Advantages	Disadvantages
Maneuverability	- Maneuverable on narrow roads with tight corners, even with multiple trailers.	- Require a separate (exclusive) roadway. - Slow maximum operating speed relative to other vehicles. - Cannot reverse.
Durability	- Moderate life span of 10-12 years. - Models with diesel engines are suitable for engine rebuilds to extend vehicle life.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- Requires special driver training for safety.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Wide fuel type availability.	- No significant disadvantages.
Cost	- Operating cost low relative to the number of passengers that can be served.	- No significant disadvantages.
Vehicle, Parts, Service Availability	- Ready supply of mechanics	- Limited number of suppliers. - Used models and lease/rent/charter opportunities less available than other vehicles. - More mechanically complex than std. buses.
Compatibility with Federally-Managed Sites	- No significant advantages.	- Large size and urban appearance may be less desirable in remote settings. - High axle loads require structurally sound roads - Not appropriate for steep terrain.
Vehicle Features	- Variety of seating arrangements. - Ready availability of ADA equipment. - Open air versions available. - Large windows and open-air versions increase viewing opportunities. - Designed for frequent stops. - Multiple doors for parallel boarding/alighting.	- Not designed for high-speed operation. - Not suitable for standard fare collection.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length per unit:	25 to 30 feet
Width per unit:	7.5 to 8.0 feet
Height per unit:	10 to 11 feet
Weight:	16,500 to 24,000 (power unit) 12,000 to 18,000 (trailer unit)
Power Source:	Gasoline, Diesel, Liquefied Natural Gas
Low Floor:	Not generally available

Economic Data	
Vehicle Cost:	\$125,000 to \$185,000 (power unit) \$100,000 to \$150,000 (trailer unit)
Vehicle Life:	10 to 12 years 250,000 to 500,000 miles

Operating Data	
Maximum Operating Speed:	25 mph
Maximum Grade:	10% to 15%
Turn Radius:	26 to 36 feet
Passengers per unit: (up to 3 units total)	
Seated:	25 to 40
Standees:	10 to 20
Total:	35 to 65
Fuel Consumption:	2 to 4 mpg

Notes

None.

BUS TRANSIT

Low Floor Transit Buses

LOW FLOOR TRANSIT BUSES

Other Names: Low Floor Vehicles

Description

Low floor transit buses were originally based on airport apron buses frequently used in Europe. Over the last five years, low floor transit buses have become a standard option for small transit buses, standard transit buses, and articulated buses. These buses are useful for moderate to high-volume, short-to-medium distance travel. The multiple wide doors and low floor design of these buses offer very efficient loading and unloading in areas with frequent stops and high volumes of simultaneous boarding and alighting movements. Low floor buses typically provide fewer seats, but more standee capacity than high floor buses. These buses require lane widths similar to those for standard transit buses. The floor of low floor vehicles is typically 11 to 14 inches above the pavement or 6 to 8 inches above a curbed loading area. This compares to a 25 to 30 inch floor height for standard transit buses.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Require 11- to 12-foot wide lanes for safe operation.
Durability	- Long life span of 12 to 15 years. - Many models have diesel engines that are suitable for rebuilds to extend vehicle life.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- No significant disadvantages.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Wide fuel type availability.	- No significant disadvantages.
Cost	- Operating cost moderate relative to number of passengers that can be served.	- High initial/capital cost. - May not be effective for low to moderate passenger loads.
Vehicle, Parts, Service Availability	- Ready supply of manufacturers & mechanics.	- Used models and lease/rent/charter opportunities less available than other vehicles.
Compatibility with Federally-Managed Sites	- No significant advantages.	- Large size and urban appearance may be less desirable in remote settings. - Large size not suited to some narrow roads. - High axle loads require structurally sound roads.
Vehicle Features	- Variety of seating arrangements. - Ready availability of equipment for ADA service. - Designed for frequent stops. - Large windows relative to vans and school buses afford better passenger viewing. - Multiple doors for easy boarding/alighting.	- Wheel wells and engine compartments reduce floor area available for seating. - Requires paved surface due to low clearance. - Unable to operate on moderate to steep grades. - Not designed for sustained high-speed operation. - Low clearance reduces max operating speed.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	30 ft., 40-45 ft, & 60 ft (articulated)
Width:	8.0 to 9.0 feet
Height:	9 to 11 feet
Weight:	30,000 to 60,000 pounds
Power Source:	Diesel, methanol, liquefied natural gas, compressed natural gas, battery, and hybrid.
Low Floor:	Essential to this bus type
Economic Data	
Vehicle Cost:	$300,000 to $400,000
Vehicle Life:	12 to 15 years 500,000 to 1,000,000 miles

Operating Data	
Maximum Operating Speed:	50 to 55 mph
Maximum Grade:	4% to 6%
Turn Radius:	30 to 50 feet
Passengers	
Seated:	10 to 30 (63 artic)
Standees:	40 to 80 (100 artic)
Total:	50 to 110 (120 artic)
Fuel Consumption:	2 to 4 mpg

Notes

Battery versions have been proven in regular service for short routes, but have limited range.
See also small transit buses, standard transit buses, and articulated transit buses

BUS TRANSIT

Motor Coaches

MOTOR COACHES

Other Names: Over-the-Road Coaches, Tour Buses

Description
These buses are designed for long-distance, high-speed travel. They are currently used by tour groups as a primary means of reaching federal lands (park units, etc.), and for inter-city travel. Concession operators are using buses of this type to provide tours within parks/public lands. Motor coaches provide high levels of passenger comfort. They are not designed for use in areas with high volumes of on and off movements. The floor level of typical motor coaches is 34 to 38 inches above the pavement. This compares to a 25 to 30 inch floor height for standard transit buses.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Require 11- to 12-foot wide lanes for safe operation.
Durability	- Very long life span of 15 years or more.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- No significant disadvantages.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Current models are diesel or compressed natural gas.	- Other alternative fuels unproven in this application.
Cost	- No significant advantages.	- High initial/capital cost. - Requires costly alterations for ADA equipment.
Vehicle, Parts, Service Availability	- Ready supply of suppliers and mechanics. - Ready supply of lease/rent/charter opportunities. - Active rebuilding and used bus market.	- No significant disadvantages.
Compatibility with Federally-Managed Sites	- Suitable for travel to and from remote areas.	- Large size and modern appearance may be less desirable in remote settings. - Large size not suited to some narrow roads. - High axle loads require structurally sound roads.
Vehicle Features	- Designed for sustained high-speed operation. - High floor and large windows enhance viewing opportunities. - High level of passenger amenities. - Comfortable for long-distance travel. - Large storage area for luggage/equipment.	- Typically only a single door for passenger boarding/alighting. - Not designed for frequent stops or short distance service. - Low capacity for size. No standee capacity as compared to similar-length std. Transit buses.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	40 to 49 feet
Width:	8.0 to 8.5 feet
Height:	11 to 13 feet (single-floor)
Weight:	34,000 to 49,000 pounds
Rear Axle Weight:	26,000 pounds
Power Source:	Diesel or Compressed Natural Gas
Low Floor:	Not generally available

Operating Data	
Maximum Operating Speed:	70 mph
Maximum Grade:	15%
Turn Radius:	30 to 45 feet
Passengers	
Seated:	45 to 65
Standees:	0 (Standees not typical)
Total:	45 to 65
Fuel Consumption:	5 to 10 mpg

Economic Data	
Vehicle Cost: (Average):	$350,000 to $500,000 ($460,000)
Vehicle Life:	15 years or more 1,000,000 to 1,200,000 miles

Notes
Double-decker version available. See double-decker page.
CNG versions have a 400-mile range.

BUS TRANSIT

Double Decker Buses

DOUBLE DECKER BUSES

Other Names: None

Description
These large buses are designed to comfortably accommodate large numbers of riders. These buses are best suited to medium to long-distance runs, where their large size can significantly reduce per-passenger operating costs. There are two major variations of this bus type: (1) reconditioned transit buses from the United Kingdom and (2) over-the-road coaches. The former tend to be shorter (typically 26 to 35 feet) than the latter.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Requires 11- to 12-foot wide lanes for safe operation. Needs high overhead clearance.
Durability	- Long life span of 10 to 15 years. - Diesel engines are suitable for rebuilds, which extend vehicle life.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- Operators less available than for smaller (single-floor) buses.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable sound levels.
Fuels	- Current models are diesel only.	- Alternative fuels untested in this application.
Cost	- Operating cost low relative to the number of passengers that can be served.	- High initial/capital cost. - High maintenance costs. - May not be cost effective for low or moderate passenger loads or seasonal use.
Vehicle, Parts, Service Availability	- Ready supply of mechanics.	- Fewer suppliers of these buses than other buses. - Used models and lease/rent/charter opportunities less available than other buses.
Compatibility with Federally-Managed Sites	- Fewer vehicles needed for high ridership. - Appearance has higher novelty/visitor appeal than similar-capacity articulated buses. - Requires less curb space than articulated bus. - Fewer vehicles needed for high ridership.	- Large size may be less desirable in remote settings. - Large size not suited to some narrow roads. - High axle loads require structurally sound roads.
Vehicle Features	- Variety of seating arrangements. - Large windows and upper deck enhance viewing opportunities. - Proven in a variety of recreational settings for tour purposes.	- Fewer doors than similar-capacity articulated buses, makes boarding/alighting slower. - Not suitable for steep grades. - Not suitable for restricted clearances. - Maintenance facility must have adequate clearance.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	26 to 45 feet
Width:	7.5 to 8.5 feet
Height:	13 to 15 feet
Weight:	45,000 to 55,000 pounds
Rear Axle Weight:	26,000 pounds
Power Source:	Diesel
Low Floor:	Not generally available.

Operating Data	
Maximum Operating Speed:	60 mph
Maximum Grade:	10%
Turn Radius:	30 to 45 feet
Passengers	
Seated:	60 to 82
Standees:	0 (standees not typical)
Total:	60 to 82
Fuel Consumption:	2 to 4 mpg

Economic Data	
Vehicle Cost:	$400,000 to $500,000
Vehicle Life:	10 to 15 years 500,000 to 1,000,000 miles

Notes
Double-decker motor coaches have the additional advantage of large storage area for luggage and equipment.

BUS TRANSIT

Electric Trolleybuses

ELECTRIC TROLLEYBUS

Other Names: None

Description
These vehicles are best used in areas of moderate to high demand for short-to-medium distance travel. The design of these buses provides for pollution free operation with efficient loading and unloading in areas with frequent stops. Because they require an overhead catenary for the power source, they have less route flexibility than the standard transit bus or articulated transit bus. Some models have battery-backup or small diesel engine capabilities, allowing for short off-wire trips.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Require 11- to 12- foot wide lanes for safe operation.
Durability	- Long life span – 20 to 30 years - Electric motor suitable for rebuilding	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- No significant disadvantages.
Noise	- Noise is similar to or less than typical passenger car.	- No significant disadvantages.
Fuels	- Electric and battery.	- Battery backup has a limited range off-wire.
Cost	- Operating cost moderate to low relative to the number of passengers that can be served.	- High initial/capital cost for vehicles. - Requires construction of overhead electrification system.
Vehicle, Parts, Service Availability	- Ready supply of mechanics.	- Relatively few suppliers compared to diesel buses. - Cannot easily be used in alternative service off-route (i.e. re-routing limited by overhead catenaries).
Compatibility with Federally-Managed Sites	- Low noise may better match remote settings than gas or diesel engines.	- Large urban appearance of vehicles and electric wire may be less desirable in remote settings. - Large size not suited to some narrow roads. - High axle loads require structurally sound roads.
Vehicle Features	- Variety of seating arrangements. - Ready availability of ADA equipment. - Suitable for frequent stops. - Large windows afford good passenger viewing opportunities. - Multiple doors for easy boarding/alighting.	- Not designed for high-speed operation. - More complex electrically than standard diesel buses.
Other	- No significant advantages.	- Providing electric power may be difficult in remote areas.

Physical Data	
Length:	35-40 ft. (std.) or 56-60 ft. (artic.)
Width:	8.0 to 9.0 feet
Height:	10 to 12 feet (vehicle only)
Weight:	23,000 to 30,000 pounds
Rear Axle Weight:	26,000 pounds
Power Source:	Overhead electric wire or battery backup.
Low Floor:	Generally available

Economic Data	
Vehicle Cost:	Approximately $550,000
Vehicle Life:	15-20 years

Operating Data	
Maximum Operating Speed:	45 mph
Maximum Grade:	15%
Turn Radius:	30-40 ft (std.) 40 to 50 ft (artic.)
Passengers	
Seated:	35 to 48 (std.), 50 to 70 (artic.)
Standees:	15 to 30 (std.), 20 to 95 (artic.)
Total:	65 to 78 (std.), 70 to 120 (artic.)
Fuel Consumption:	110 to 170 kw at 460 to 600 volts DC

Notes
Overhead electrification power system costs approximately $0.5 Million to $1.0 Million per mile to construct. Electric substations cost approximately $1.0 Million each.
Requires special training if articulated.

RAIL / GUIDED TRANSIT






INTRODUCTION TO RAIL / GUIDED TRANSIT

Fixed guideway transit is most well known for its capability in moving very large numbers of people between two points or along well-defined corridors. Fixed guideway systems, like bus transit, have been applied to all types of settings from the more common urban settings to more specialized settings at airports or theme parks.

Fixed guideway transit systems range from completely manned operation to full automation. The level of passenger interaction and the availability of the operator to assist passengers aboard a vehicle depend on the specific rail technology in use. Fixed guideway transit systems are typically designed to operate in settings that are at least partially separated from mixed traffic. To achieve the necessary physical separation, the guideway may be grade-separated, elevated, tunneled, or fenced-off. This type of transit has fixed routes with fixed station stops.

- First, because they can be operated in trains, fixed guideway transit vehicles can carry large passenger volumes at a lower labor cost per passenger than bus transit.
- Second, most of the fixed guideway transit vehicles are powered by electricity, which eliminates mobile source emissions and much of the noise associated with internal combustion engines. Fixed guideway transit is especially suitable for relatively compact areas in which travel demand is high, walking distances are excessive, and use of private vehicles is either impractical or incompatible with the desired environment.
- Third, fixed guideway transit can deliver high-quality, high-frequency, high-speed service in environments with very tight operating tolerances. High-capacity fixed guideway transit vehicles can be designed to operate along alignments through restricted rights-of-way, including bridges and tunnels.

The disadvantages of fixed guideway transit make it a technology only suitable for narrowly defined application.

- First and foremost, fixed guideway transit has very high initial capital costs relative to bus systems. Costs range upward from more than $1.0 Million per mile. Fixed guideway infrastructure is not something that should be implemented without stable, very high levels of demand. The requirements for grade separation of the infrastructure or overhead wires (if electric) may also have visually intrusive impacts in remote settings.
- Second, the guideway itself limits the service area of fixed guideway systems to a linear corridor. Guideway facilities can not be easily moved (without great cost) to adapt to changes in demand. Often, bus feeder systems are necessary to collect riders from wider geographic areas.
- Third, relative to the bus industry, there are fewer numbers of suppliers. Rail cars are also expensive and there is limited opportunity for temporary types of vehicle use/ownership (such as lease, rental, or charter). Some fixed guideway technologies are proprietary and must be purchased as a complete system from the supplier; this may further limit the flexibility of a site to procure a system that best meets its needs.

The information sheets below are organized to first introduce vehicles that had greater historical prominence than they do today (historic trolleys and narrow gauge railroad). The second set of vehicles is primarily used in applications with short, shuttle-type trip lengths (cableway shuttle transit, people movers, and monorails). The last two vehicle types, light rail and conventional passenger rail, are more typical for moderate to long trip lengths.

RAIL / GUIDED TRANSIT

Historic Trolleys

HISTORIC TROLLEYS

Other Names: Streetcars

Description
Historic trolleys continue to operate in many locations, especially outside of the United States. Historic trolleys feature electrically-powered rail cars with an overhead electric wire (catenary) as the power source. Most trolleys are single-unit vehicles and do not typically operate in trains. Stations or stops are generally 1/4 to 1/2 mile apart.

Characteristic	Advantages	Disadvantages
Maneuverability	- At slow speeds, trolleys are able to make tight turns at typical urban roadway intersections.	- Relatively difficult to change routes and boarding points in response to varying demand. - Priority treatment over existing auto traffic and freight train traffic is desirable.
Durability	- Long life span possible with continued rehabilitation.	- Rehabilitation efforts rely on the remanufacture of historic parts or salvage from retired vehicles.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for standard buses.
Noise	- Electric motors provide a similar noise level to passenger autos.	- Warning horns or bells must be sounded at street crossings to alert pedestrians and drivers of their presence.
Fuels	- Electric, gasoline	- No significant disadvantages.
Cost	- Operating cost moderate relative to the number of passengers that can be served. - Lower capital cost relative to elevated rail systems.	- High initial/capital cost relative to bus vehicles. - Requires high cost investment in the physical system of rails, overhead wires, and stations. - Right-of-way maintenance costs higher than for buses due to overhead wire, tracks, & switches.
Vehicle, Parts, Service Availability	- No significant advantages.	- Requires specialized maintenance facilities and skilled personnel. - Vehicles and parts available only on used market.
Compatibility with Federally-Managed Sites	- Easily recognized routes and boarding points. - Tracks, like roads, can be crossed by pedestrian and vehicular traffic, and wildlife.	- Overhead wires and supporting poles may be considered visually intrusive in remote settings - Sufficient electrical power may not be available in remote settings.
Vehicle Features	- Multiple doors for easy boarding/alighting. - Large windows afford good viewing. - Historic appearance may have more novelty/visitor appeal than other rail technologies. - Historic appearance may be better suited for remote settings.	- Difficult to implement in areas with steep grades. - More complex mechanically than std. buses. - Requires large service/maintenance facility. - Not typically ADA compliant without modification.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	30 to 50 feet
Width:	7 to 9 feet
Height:	8 to 12.5 feet (vehicle only) 108 to 20 feet (with overhead wire)
Weight (empty):	30,000 to 50,000 lbs.
Power Source:	Overhead Electricity
Right of Way:	16 to 25 feet (single) 22 to 40 feet (double)
Low Floor:	Not typically available

Economic Data	
Vehicle Cost:	$150,000 - $350,000 restored original $600,000 - $900,000 new replica
System Cost:	$5 to $40 Million per mile (surface)
Vehicle Life:	20-30 years

Operating Data	
Maximum Operating Speed:	30 to 40 mph
Maximum Grade:	4 to 8%
Turn Radius (minimum):	34 to 50 feet
Passengers (per car)	
Seated:	16 to 60
Standees:	15 to 40
Total:	31 to 100

Notes
A number of cities, including San Francisco, Lowell (NPS), Portland, Dallas, San Jose, Memphis, New Orleans (Riverfront), Kenosha, and Seattle have part or full-time historic trolley service.
Several specialty firms manufacture trolleys which resemble old style streetcars, but contain new or rebuilt components.

RAIL / GUIDED TRANSIT

Narrow Gauge Railroad

NARROW GAUGE RAILROAD

Other Names: None

Description
Narrow gauge passenger rail operates in select locations throughout the U.S. Narrow gauge railroads are most typically associated with historic rail lines that have become tourist attractions. Narrow gauge rail would be uncommon for new construction, with the exception of amusement park style applications. Similar to conventional rail, the train consists of one or more un-powered passenger cars pushed or pulled by a locomotive. The propulsion system is typically a diesel-mechanical engine, or if historic, a coal-fired steam engine. As opposed to standard gauge rails which are 4 feet 8 ½ inches from inside to inside edge of rail, narrow gauge rails are variously set at 2 feet or 3 feet apart.

Characteristic	Advantages	Disadvantages
Maneuverability	- At slow speeds, the narrow gauge of the track and wheels allows it to navigate tighter curves than standard gauge vehicles.	- Relatively difficult to change routes and boarding points in response to varying demand.
Durability	- Very long life span of 30 – 50+ years	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for standard trains.
Noise	- No significant advantages.	- Warning horns and bells used when approaching stations. - Crossing bells and gates used at street crossings. - Diesel motors or steam engines may create objectionable sound levels compared to LRT.
Fuels	- Diesel or Steam (Oil- or Coal-Fired for Steam)	- Electric narrow gauge not typically available.
Cost	- Operating cost low relative to the number of passengers that can be served. - Lower capital cost relative to other rail technologies.	- High initial/capital cost relative to bus vehicles. - Requires high cost investment in the physical system of fixed guideway and stations. - Right-of-way maintenance costs higher than for buses due to tracks and switches.
Vehicle, Parts, Service Availability	- No significant advantages.	- Typically only available as a used or refurbished vehicle. - Requires specialized maintenance facilities and skilled personnel.
Compatibility with Federally-Managed Sites	- Tracks can be crossed by pedestrian and vehicular traffic, and wildlife. - Fewer vehicles needed for high or very high ridership. - If historic, the appearance could have more appeal in a remote setting as compared to other rail technologies.	- See noise.
Vehicle Features	- Variety of seating arrangements. - Large windows afford good viewing opportunities. - Can be implemented in areas with moderate grades.	- More complex mechanically than std. buses. - Less efficient boarding/alighting than light rail transit due to fewer doors per car. - Requires large service/maintenance facility.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data (per unit)

Length:	34 to 85 feet
Width:	9 to 12 feet
Height:	10 to 15 feet
Weight (empty):	35,000 to 90,000 pounds (cars) 250,000 pounds (engine)
Power Source:	Diesel or Steam (Oil- or Coal-Fired)
Right of Way:	16 to 25 feet (single) 22 to 40 feet (double)
Low Floor:	Not generally available.

Economic Data

Vehicle Cost:	$100,000 to $500,000 (restored/replica)
System Cost:	$5 to $10 Million per mile
Vehicle Life:	20 to 40 years (coaches) 50+ years (engines)

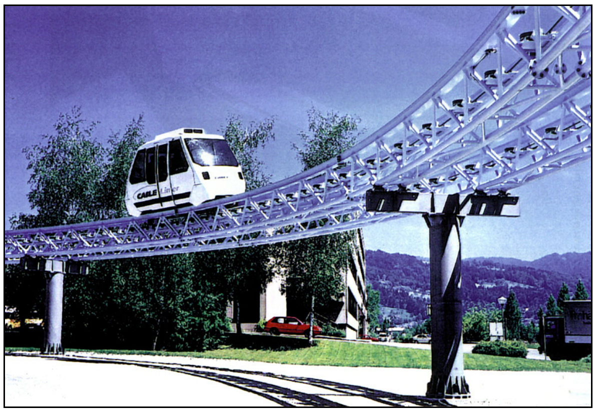
Operating Data

Maximum Operating Speed:	45 to 60 mph
Maximum Grade:	2%
Turn Radius (minimum):	60 to 100 feet
Passengers (per car)	
Seated:	30 to 100
Standees:	50 to 100
Total:	80 to 200

Notes
Original (antique) narrow gauge vehicles are available, but are extremely rare and reliable vehicle cost information is unavailable.

RAIL / GUIDED TRANSIT

Moving Cableway Shuttle Transit



MOVING CABLEWAY SHUTTLE TRANSIT

Other Names: Ropeway Transit

Description

This transit technology uses lightweight vehicles propelled horizontally by a moving cable similar to gondolas, aerial trams, or funiculars. While it can be at-grade or below-grade (tunneled) it has typically been part of an elevated system. Because the propulsion system is the cable, the vehicles do not have engines, motors, or braking systems and can be very light in comparison to self-propelled vehicles. For the elevated application, the structure for this technology is a combination of steel pylons and space-frame beams; no solid concrete or reinforced concrete beams are required. This technology is fully automated and requires only a centralized operator for multiple moving vehicles or trains of vehicles. Depending upon the vehicle type, this technology is applicable for corridors 0.2 to 3 miles in length.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Relatively difficult to change routes and boarding points in response to varying demand.
Durability	- Very long vehicle life span of 25 to 30 years.	- No significant disadvantages.
Operator Availability	- No operator required.	- No significant disadvantages.
Noise	- Does not require the warning horns and bells of an at-grade system (elevated version assumed). - Noise along the track is at or below the sound level of passenger cars. Noise level at terminal stations can be insulated.	- No significant disadvantages.
Fuels	- Diesel or Electric motor to drive the Cable	- No other fuel types available at this time.
Cost	- Operating cost low to moderate relative to the number of passengers that can be served.	- High initial/capital cost relative to bus systems. - Requires high cost investment in the physical system of (elevated) rails and electrical systems. - Right-of-way maintenance costs higher than for buses due to elevated (or tunneled) sections.
Vehicle, Parts, Service Availability	- No significant advantages	- Few suppliers. - Requires specialized maintenance facilities and skilled personnel. - Proprietary technologies limit choices when system expansion or changes are required.
Compatibility with Federally-Managed Sites	- Easily recognized routes and boarding points. - Support structure more transparent/less obtrusive than a monorail box beam. - Elevated system provides excellent viewing opportunities.	- Support structure more visually obtrusive than at grade rail systems, or roadways.
Vehicle Features	- Variety of seating arrangements available. - Multiple doors for easy boarding/alighting. - Floor level boarding is ADA compliant.	- More complex mechanically than standard buses.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	17 to 45 feet
Width:	7.5 to 10 feet
Height:	9.5 feet
Weight (empty):	12,000 to 30,000 pounds
Power Source:	Moving Cable (Diesel or Electric Cable Motor)
Right of Way:	8 to 12 feet (single) 17.5 to 25 feet (double)
Low Floor:	Yes. Floor level boarding by design.

Operating Data	
Maximum Operating Speed:	15 to 30 mph
Maximum Grade:	12% to 15%
Turn Radius (minimum):	100 to 270 feet
Passengers (per car, up to 3-car trains)	
Seated:	10 to 40
Standees:	20 to 160
Total:	30 to 200

Economic Data	
Vehicle Cost:	$100,000 to $300,000
System Cost:	$16 to $32 Million per mile
Vehicle Life:	25 to 30 years

Notes

None.

RAIL / GUIDED TRANSIT

People Movers

PEOPLE MOVERS

Other Names: Automated People Mover (APM)

Description

People movers have been proven in daily operation in airports, activity centers, and downtown areas. Examples of this technology in providing line-haul rapid transit service exist in the United States, Canada, and Europe. People mover systems employing rubber tires and steel wheels have been successfully implemented. Automated operation allows headways between vehicles to vary in response to demand. These systems are most appropriate for short to medium distance travel. People movers are typically grade-separated, being either elevated or tunneled underground.

Characteristic	Advantages	Disadvantages
Maneuverability	- Very short headways possible due to automation. - Grade separation allows superior speed and reliability. - Capable of very tight turns at low speeds.	- Relatively difficult to change routes and boarding points in response to varying demand.
Durability	- Long to very long vehicle life span of 20 to 25 years.	- No significant disadvantages.
Operator Availability	- Not Applicable.	- No significant disadvantages.
Noise	- Does not require the warning horns and bells of an at-grade system - Electric motors provide a similar noise level to passenger autos.	- No significant disadvantages.
Fuels	- Electric.	- No other fuel availability at this time.
Cost	- Operating cost low, relative to the number of passengers that can be served. - With automation, labor costs are minimized.	- High initial/capital cost relative to bus vehicles. - Requires very high cost investment in the physical system of grade separation and stations - Right-of-way maintenance costs higher than for buses due to grade separations and electrical systems.
Vehicle, Parts, Service Availability	- No significant advantages.	- Limited number of suppliers. - Requires specialized maintenance facilities and skilled personnel. - Proprietary technologies limit choices when system expansions or changes are required.
Compatibility with Federally-Managed Sites	- Easily recognized routes and boarding points. - Can respond to demand fluctuations without a large standby force. - Elevated system provides excellent viewing opportunities. - Appearance has a higher novelty/visitor appeal than other guideway transit systems. - Allows free movement of pedestrians and wildlife.	- If elevated, structure less transparent and more visually obtrusive than other guideway systems. - Modern appearance may be less desirable in remote settings. - If tunneled, viewing opportunities are limited. - Sufficient electrical power may not be available in remote settings. - Limited opportunities for informal stops.
Vehicle Features	- Variety of seating arrangements available. - Multiple doors for easy boarding/alighting. - Floor level boarding is ADA compliant.	- Difficult to implement in areas with steep grades. - More complex electrically than most other technologies.
Other	- Proven in downtown and airport locations worldwide.	- Elevated stations are large and complex.

Physical Data

Length:	11 to 58 feet
Width:	6 to 10 feet
Height:	8 to 12 feet
Weight (empty):	9,000 to 40,000 pounds
Power Source:	Electric current
Right of Way:	8 to 16 feet (single)
	16 to 35 feet (double)
Low Floor:	Yes. Floor level boarding by design.

Operating Data

Maximum Operating Speed:	50 to 60 mph
Maximum Grade:	4% to 8%
Turn Radius (minimum):	26 to 180 feet
Passengers (per car)	
Seated:	8 to 65
Standees:	40 to 140
Total:	48 to 205

Economic Data

Vehicle Cost:	$1.0 to $2.0 Million
System Cost:	$40 to $100 Million/mile
Vehicle Life:	20 to 25 years

Notes

None.

RAIL / GUIDED TRANSIT

Monorail

MONORAIL

Other Names: None

Description

Monorail is a variation of group rapid transit that employs a single, relatively narrow beam to support the transit vehicles. Vehicles may either straddle the beam or be suspended from it. Vehicles may either have human operators or be fully automated. Vehicles may travel as single units or be linked together in trains. The design of monorail allows the guideway to be smaller, lighter, less obtrusive, and potentially less expensive than other fully elevated transit systems. Like people movers, monorail systems must be fully protected from pedestrian and wildlife crossings. In the United States, monorail has seen limited applications. It has been implemented in recreational areas or amusement parks such as Disneyland/Disneyworld and short (approx. 1.0 miles) applications such as downtown Seattle, and at the Newark, NJ airport.

Characteristic	Advantages	Disadvantages
Maneuverability	- At slow speeds, monorail is able to approximate the turning radius of LRT vehicles. - Grade separation allows superior speed.	- Relatively difficult to change routes and boarding points in response to varying demand.
Durability	- Very long vehicle life of 30 years.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for std. buses.
Noise	- Does not require the warning horns and bells of an at-grade system. - Electric motors provide a similar noise level to passenger autos.	- No significant disadvantages.
Fuels	- Electric.	- No other fuel availability at this time.
Cost	- Operating cost low to moderate, relative to the number of passengers that can be served. - If automated, labor costs are minimized.	- High initial/capital cost relative to bus vehicles. - Requires high cost investment in the physical system of elevated box beams and stations. - Right-of-way maintenance costs higher than for buses due to elevation and electrical systems.
Vehicle, Parts, Service Availability	- No significant advantages.	- Requires specialized maintenance facilities and skilled personnel. - Relatively few suppliers. - Proprietary technologies limit choices when system expansion or changes are required.
Compatibility with Federally-Managed Sites	- Easily recognized routes and boarding points. - Narrow width of guideway beam makes it less obtrusive than other fully elevated systems. - Elevated system provides excellent viewing opportunities. - Appearance has higher novelty/visitor appeal than other guideway transit systems. - Allows free movement of pedestrians and wildlife.	- Elevated structure more visually obtrusive than at-grade rail systems or roadways. - Sufficient electrical power may not be available in remote settings. - Modern appearance may be less desirable in remote settings. - Limited opportunities for unscheduled stops.
Vehicle Features	- Variety of seating arrangements available. - Multiple doors for easy boarding/alighting	- Difficult to implement in areas with steep grades. - More complex electrically than most other technologies. - Requires large area for switching and servicing.
Other	- Proven in amusement park and airport settings.	- Elevated stations are large and complex.

Physical Data (per unit)	
Length:	24 to 40 feet
Width:	7.0 to 9.0 feet
Height:	9.0 to 11.0 feet
Weight (empty):	18,000 to 22,000 pounds
Power Source:	Electric Current 150 to 500 kW at 600-750 V DC
Right of Way:	8 to 16 feet (single) 16 to 35 feet (double)
Low Floor:	Yes. Floor level boarding by design.

Operating Data	
Maximum Operating Speed:	35 to 55 mph
Maximum Grade:	4% to 8%
Turn Radius (minimum):	50 to 250 feet
Passengers (per car)	
Seated:	10 to 20
Standees:	25 to 70
Total:	35 to 90

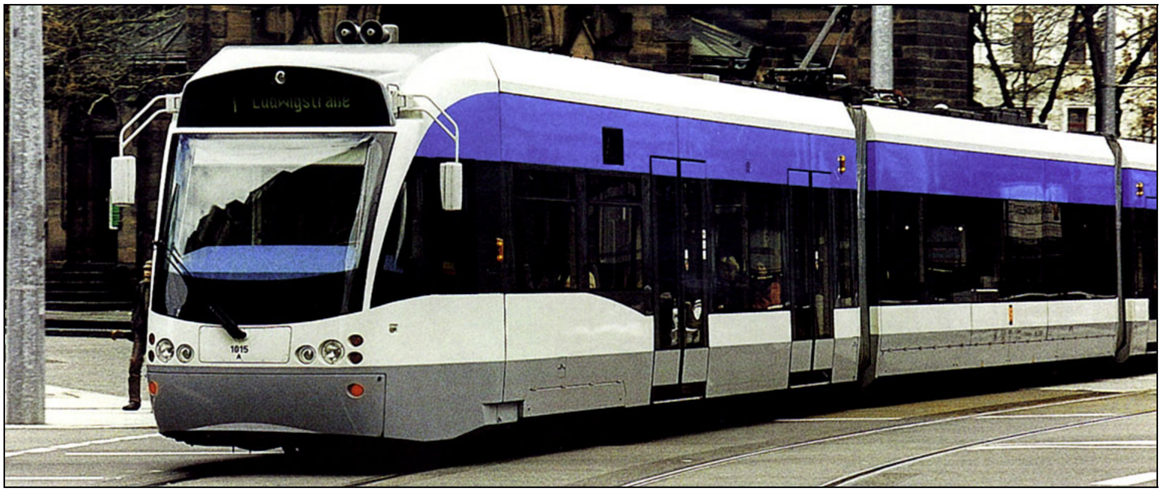
Economic Data	
Vehicle Cost:	$1.0 to $2.0 Million
System Cost:	$40 to $80 Million per mile
Vehicle Life:	30 years

Notes

None.

RAIL / GUIDED TRANSIT

Light Rail Transit



LIGHT RAIL TRANSIT (LRT)

Other Names: Electrified Light Rail, Street Trams, Trolleys

Description

Light rail transit operates in more than 20 urban areas in the U.S. and Canada. LRT features electrically-propelled rail cars, operated singly or in short trains, using an overhead electric wire (catenary) as the power source. Two light rail vehicle types are in service: single unit cars or articulated cars. As a system, LRT generally has stations spaced 1 to 2 miles apart (closer in major activity areas), with total corridor lengths not generally exceeding 15 to 20 miles. Electric trolleys (see separate page) are a variation of light rail transit which offer historic visual appeal along with many of the transportation advantages of modern LRT. Some self-propelled rail transit vehicles (a.k.a. diesel multiple unit or DMU) can also simulate light rail service.

Characteristic	Advantages	Disadvantages
Maneuverability	- At slow speeds LRT is able to make tight turns at typical urban roadway intersections.	- Relatively difficult to change routes and boarding points in response to varying demand. - Priority treatment over existing auto traffic and freight train traffic is desirable.
Durability	- Very long life span of 25 to 30 years	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for standard buses.
Noise	- Electric motors provide a similar noise level to passenger autos.	- Warning sounds must be made at street crossings to alert peds and drivers of their presence.
Fuels	- Electric or Diesel.	- No other fuel availability at this time.
Cost	- Operating cost low to moderate, relative to the number of passengers that can be served. - Lower capital cost relative to elevated rail technologies.	- High initial/capital cost relative to bus systems. - Requires high cost investment in the physical system of guideway, overhead wires and stations. - Right-of-way maintenance costs higher than for buses due to overhead wire, tracks, & switches.
Vehicle, Parts, Service Availability	- Wide range of suppliers. - Standard equipment proven in U.S. operations.	- Requires specialized maintenance facilities and skilled personnel.
Compatibility with Federally-Managed Sites	- Easily recognized routes and boarding points. - Tracks, like roads, can be crossed by pedestrian & vehicular traffic, and wildlife. - Fewer vehicles needed for high or very high ridership.	- Overhead wires ands supporting poles may be considered visually intrusive in remote settings. - Sufficient electrical power may not be available in remote settings. Diesel versions may create objectionable sound levels.
Vehicle Features	- Variety of seating arrangements - Multiple doors for easy boarding/alighting. - Large windows afford good viewing.	- Difficult to implement in areas with steep grades. - More complex mechanically than std. buses. - Not generally suitable for traditional fare collection. - Requires large service/maintenance facility.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data (Per Car)	
Length:	50 to 90 feet
Width:	7 to 9 feet
Height:	8 to 12.5 feet (vehicle only) 18 to 20 feet (w/ overhead wire)
Weight (empty):	67,000 to 103,000 pounds
Power Source:	Overhead Electric
Right of Way:	16 to 25 feet (single) 22 to 40 feet (double)
Low Floor:	Becoming available. Not as common in the U.S.

Economic Data	
Vehicle Cost (Average):	$2.0 to $3.0 Million ($2.308 Million)
System Cost:	$20 to $40 Million per mile (surface)
Vehicle Life:	25 to 30 years

Operating Data	
Maximum Operating Speed:	35 to 60 mph
Maximum Grade:	4% to 8%
Turn Radius:	47 to 82 feet
Passengers (per car)	
Seated:	32 to 90
Standees:	40 to 110
Total:	72 to 200
Power Requirement:	400 to 1500 kw at 600 to 750 volts DC

Notes

Typical maximum of 4 cars per train, limited by area for boarding/alighting at stations or the length of the street between intersections.

RAIL / GUIDED TRANSIT

Conventional Passenger Rail

CONVENTIONAL PASSENGER RAIL

Other Names: Commuter Rail, Inter-City Rail, Inter-City Train (ICT)

Description
Conventional passenger rail operates throughout the U.S. Typically the train consists of one or more un-powered passenger cars pushed or pulled by a locomotive. The propulsion system is typically a diesel-electric motor. As part of a system, conventional commuter rail generally has stations spaced five or more miles apart, with corridor lengths of 20 to 100 miles. Conventional intercity passenger rail is compatible with (may share track with) active freight railroad operations. Some self-propelled vehicles (a.k.a. diesel multiple units or DMU) may also operate consistent with conventional passenger rail.

Characteristic	Advantages	Disadvantages
Maneuverability	- Generally operate at higher speeds than light rail.	- Relatively difficult to change routes and boarding points in response to varying demand.
Durability	- Very long life span of 25 to 30 years.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special crew training for safety. - Operators less available than for standard buses or light rail.
Noise	- No significant advantages.	- Warning horns used when approaching stations. - Crossing bells and gates used at street crossings. - Diesel motors may create objectionable sound levels compared to LRT.
Fuels	- Diesel or diesel electric.	- No other fuel availability at this time.
Cost	- Operating cost very low relative to the number of passengers that can be served. - Lower capital cost relative to LRT, monorail, and other rail technologies.	- High initial/capital cost relative to bus systems. - Requires high cost investment in the physical system of rails and stations. - Right-of-way maintenance costs higher than for buses due to tracks and switches.
Vehicle, Parts, Service Availability	- Wide range of suppliers.	- Requires specialized maintenance facilities and skilled personnel.
Compatibility with Federally-Managed Sites	- Tracks can be crossed by pedestrian & vehicular traffic, and wildlife. - Fewer vehicles needed for high or very high ridership.	- See noise.
Vehicle Features	- Variety of seating arrangements. - Large windows afford good viewing opportunities.	- Difficult to implement in areas with steep grades. - More complex mechanically than std. buses. - Less efficient boarding/alighting than light rail transit due to fewer doors per car. - Requires large service/maintenance facility.
Other	- No significant advantages.	- No significant disadvantages.

Length:	70 to 90 feet
Width:	9 to 12 feet
Height:	10 to 15 feet (single level) 14 to 16 feet (double-decker)
Weight (empty):	70,000 to 120,000 pounds (cars) 250,000 to 300,000 pounds (engine)
Power Source:	Diesel or Diesel-Electric
Right of Way:	16 to 25 feet (single) 22 to 40 feet (double)
Low Floor:	Not generally available. Floor level boarding by design.

Operating Data

Maximum Operating Speed:	55 to 79* mph conventional
Maximum Grade:	2 %
Turn Radius (minimum):	90 to 500 feet

Passengers (per car), sl=single level, dd=double deck

Seated:	38 to 110 sl, 110 to 164 dd
Standees:	50 to 145 sl, 145 to 200 dd
Total:	88 to 255 sl, 255 to 364 dd

Economic Data

Vehicle Cost (Average):	$1.0 to $2.0 Million ($1.218 Million)
System Cost:	$5 to $10 Million per mile
Vehicle Life:	30 years

Notes
Passenger cars available in double-decker versions.

*FRA requires special signaling/train control systems for speeds above 79 mph.

HIGH GRADIENT TRANSIT

INTRODUCTION TO HIGH GRADIENT TRANSIT

High gradient transit technologies have been devised for areas with special needs or constraints that are not well served by traditional bus or rail systems. Characteristics associated with high gradient transit technologies include steep grades, mountainous terrain, and potential disruption to wetlands or other sensitive environments. In some cases, tourist attractions have used these systems to capitalize on the novelty value of an exotic transportation mode. This technology category includes cog railways, funiculars, and aerial cable systems.

High gradient transit technologies have all of the characteristics of fixed guideway transit technologies, excepting that they are not limited to grades under 10%. Like fixed guideway transit, high gradient transit is partially to fully automated and the level of passenger interaction and assistance on the part of the operator depends on the specific rail technology in use. High gradient transit is designed to operate in settings fully separated from the mixed-traffic setting of bus transit, and has fixed routes with fixed station stops.

In settings with steep slopes and /or other environmental constraints, high-gradient technologies often offer the most direct and least-damaging transportation facility alignment. Second, most high gradient transit technologies emit no mobile source emissions of air pollutants and their point source emissions of air pollutants and noise are both readily mitigated.

There are two main disadvantages to this type of transit. First, with the exception of the cog railway, it is only applicable to relatively short distances. Second, there are few suppliers, resulting in a limited availability of these vehicles for purchase, lease, rental, or charter.

Cog railways or rack railways were initially implemented to allow conventional trains to ascend steep grades, enabling passengers to make a through trip rather than transfer to a funicular or aerial cable system. While typically used in mountainous areas on non-mainline railways, rack sections can be used on a railway where a steep grade may occur and with other rail modes. Some systems apply a combination of cog and normal rail adhesion technology.

Funiculars (or inclined railways) have typically been implemented to provide access between points of significantly different elevation or along steep hills. They represent the most efficient means of ascending steep slopes over short distances. Funiculars have been implemented in parks and in urban areas to facilitate pedestrian movements. In the United States, funiculars operate successfully in cities such as Pittsburgh, PA and Chattanooga, TN and Johnstown, PA. Funiculars use a rail-based guideway with a moving cable propulsion system.

Gondolas and reversible tramways are the principal types of aerial cable systems. Such operations, most often seen in ski areas, transport people individually or in small groups. Larger aerial cable systems provide line-haul transportation at activity centers. These systems employ larger vehicles and often provide transportation across geographical barriers such as lakes, in cases where a bridge is undesirable. An urban application of an aerial tramway connects Manhattan with Roosevelt Island, New York.

The first two technologies in this section, cog railways and funiculars, most closely resemble the majority of those discussed in the fixed guideway transit section above. The latter two technologies, aerial tramways and gondolas, have elements in common only with the moving cableway shuttle transit of the previous section.

HIGH GRADIENT TRANSIT

Cog Railways

COG RAILWAYS

Other Names: None

Description
Cog rail technology was developed to allow conventional trains to negotiate steep slopes in mountainous terrain. Cog rail vehicles can be powered by diesel engines, as on Pikes Peak in Colorado, or by electricity, as on the Swiss Mountain Railway system in Europe. Railway lines can employ cog or rack propulsion on steep sections and standard adhesion propulsion on the remainder of the line.

Characteristic	Advantages	Disadvantages
Maneuverability	- Ideal for steep slopes.	- Relatively difficult to change routes and boarding points in response to varying demand.
Durability	- Very long vehicle life of 30 years.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for standard buses.
Noise	- Electric motors provide a similar noise level to passenger autos.	- Diesel motor versions may create objectionable noise levels.
Fuels	- Diesel or Electric.	- No other fuels available.
Cost	- Operating cost low to moderate relative to the number of passengers that can be served.	- High initial/capital cost relative to bus vehicles. - Requires high cost investment in the physical system of rails, stations (& electrification). - Right-of-way maintenance costs higher than for buses due to track, switches (& overhead wire).
Vehicle, Parts, Service Availability	- No significant advantages.	- Requires specialized maintenance facilities and skilled personnel. - Few suppliers.
Compatibility with Federally-Managed Sites	- Easily recognized routes and boarding points. - Tracks, like roads, can be crossed by pedestrian & vehicular traffic, and wildlife.	- If electric, overhead wires and supporting poles may be considered visually intrusive in remote settings. - If electric, sufficient electrical power may not be available in remote settings.
Vehicle Features	- Variety of seating arrangements. - Multiple doors for easy boarding/alighting. - Large windows afford good viewing. - Can use rack propulsion on steep grades and conventional propulsion elsewhere. - Suitable for long-distance operation. - Appearance may have more consistency with remote settings than most other technologies.	- Relatively slow moving on rack sections. - Requires high block or platform for disabled boarding. - Requires large service/maintenance facility.
Other	- Technology in use for many years.	- No significant disadvantages.

Physical Data	
Length:	50 to 55 feet (single car) 100 to 125 feet (double car)
Width:	9.7 feet
Height:	12 to 13 feet
Weight:	80,000 pounds approximate (per car)
Power Source:	Diesel, electric
Right of Way:	13 feet (single track) 26 feet (double track)
Low Floor:	Not generally available. Some floor level boarding by design (platform).

Operating Data	
Maximum Operating Speed:	20 mph
Maximum Grade:	12.5% to 25%
Turn Radius:	262 to 328 feet
Passengers	
Seated:	90 to 120
Standees:	60 to 80
Total:	150 to 200
Power Requirement:	800-2,000 kW (electric propulsion)

Economic Data	
Guideway	$2.5 to $10 Million/mile
Vehicles	$4.5 to $5.5 Million
Estimated Life	30 years

Notes
None.

HIGH GRADIENT TRANSIT

Funiculars

FUNICULARS

Other Names: Inclined Planes

Description

Funiculars or inclined planes function as inclined elevators, providing access over steep slopes. Funiculars typically have only two vehicles. Each vehicle serves as a counter weight to the other on the cable, with one vehicle moving in each direction simultaneously. Funiculars can either be built as a set of two tracks or a single track with a small double-track passing section. Funiculars involve site-specific design and the development of customized equipment. Its application in federally-managed public lands would be limited to short travel between activity areas to viewpoints.

Characteristic	Advantages	Disadvantages
Maneuverability	- Ideal for areas with steep grades. - Operation can be fully automated.	- Relatively difficult to change routes and boarding points in response to varying demand. - Straight line travel only.
Durability	- Very long vehicle life of 30 years.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for std. buses.
Noise	- Noise level along the track is at or below the sound level of passenger cars. Noise level at the terminal stations can be insulated.	- No significant disadvantages.
Fuels	- Diesel or electric motor to drive the cable.	- No other fuel types available at this time.
Cost	- Lower capital cost to install a high gradient funicular on a short segment than construct a longer facility with a lower gradient.	- High initial/capital cost relative to bus vehicles. - Requires a high cost investment in the physical system of rails, cables, and stations. - Moderate to high operating cost, relative to the number of passengers that can be served.
Vehicle, Parts, Service Availability	- No significant advantages	- Requires site-specific design. - Few suppliers. - Proprietary technologies limit choices when system expansion or changes are required.
Compatibility with Federally-Managed Sites	- All weather operation. - No off-line maintenance required. - High gradient, at-grade facility may be less visually obtrusive than either aerial technology or longer at-grade facility with a lower gradient. - Appearance has higher novelty/visitor appeal than some other guideway transit systems.	- Typical track installation is not easily crossed by wildlife or pedestrians. - In some remote settings, this technology may be more visually intrusive than gondolas or aerial trams due to the removal of vegetation. - Limited opportunities for informal stops. - If electric, electricity may not be available in remote locations. Diesel may have emissions.
Vehicle Features	- Multiple doors for easy boarding/alighting. - Not as likely to limit people with vertigo. - Easier emergency unloading than gondolas or aerial systems. - Steep gradient affords good viewing.	- Relatively low speed. - Applicable only to short distance travel. - Seating arrangements limited, relative to other technologies.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	34 to 102 feet
Width:	7.5 to 8.5 feet
Height:	9 to 12 feet
Weight:	25,000 to 65,000 pounds
Power Source:	Moving Cable
Right of Way:	15 to 30 feet
Low Floor:	Not generally available. Floor level boarding by design

Operating Data	
Maximum Operating Speed:	23 mph
Maximum Grade:	8^{o} to 62^{o}
Passengers (per car)	
Seated:	20 to 60
Standees:	0 to 40
Total:	20 to 100

Economic Data	
Vehicle Cost:	$500,000 to $1.0 Million
Guideway Cost:	$4.2 to $6.9 Million/Mile
Vehicle Life:	30 Years

Notes

None.

HIGH GRADIENT TRANSIT

Aerial Tramways

AERIAL TRAMWAYS

Other Names: None

Description

Aerial tramways provide a cost-effective means of accessing rugged, mountainous terrain. Typically used at ski resorts and at tourist attractions, tramways provide novelty appeal as well as transportation service. Tramways may also be used to cross physical barriers, such as rivers, lakes, or canyons. An urban transport application of this technology provides service to Roosevelt Island in New York City. Aerial trams operate on a closed-loop cable system, meaning they only travel up and back on the same cable or require special turn around facilities to be transferred from the cable moving in one direction to the cable moving in the opposite direction.

Characteristic	Advantages	Disadvantages
Maneuverability	- Ideal for areas with steep grades or other topographical barriers. - Can be mostly automated.	- Relatively difficult to change routes and boarding in response to varying demand. - Straight-line travel only, unless multiple systems are used.
Durability	- Moderate length life span of tram cabins.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for standard buses.
Noise	- Noise level along the cable is below the sound level of passenger cars. Noise level at the terminal stations can be insulated.	- No significant disadvantages.
Fuels	- Diesel or electric motor to drive the cable.	- No other fuel types available at this time.
Cost	- Relatively low initial/capital cost relative to rail technologies, including funiculars. - Operating cost low to moderate, relative to the number of passengers that can be served.	- High initial/capital cost relative to bus vehicles. - Requires a high cost investment in the physical system of towers, cables, and stations.
Vehicle, Parts, Service Availability	- Relatively simple maintenance.	- Requires site-specific design. - Few suppliers.
Compatibility with Federally-Managed Sites	- Marginal impact on surface vegetation. - Does not form a barrier to wildlife or pedestrian movements. - Appearance has a higher recreational appeal than some other guideway transit systems. - Allows management of visitor movement and interpretive opportunities.	- In some remote settings, this technology may be more visually intrusive than funiculars due to the prominence of towers in certain locations. - Turnaround facilities are complicated.
Vehicle Features	- Variety of seating arrangements. - High speed relative to funiculars. - Provides excellent viewing opportunities in appropriate terrain. - Large capacities per tram cabin.	- Reduced speeds at support points. - May limit people with vertigo. - Passengers may feel crowded in large groups. - Limited system lengths due to lower tension exerted on the cable for acceleration as distance increases. - Line branching not possible; passengers must transfer.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	9.8 to 30 feet
Width:	8.7 to 13.8 ft.
Height:	8.5 to 9.8 feet
Weight:	4,400 to 19,850 lbs.
Power Source:	Cable propulsion
Right of Way:	
Horizontal	25 to 50 feet
Vertical	40 feet
Low Floor:	Floor level boarding by design.

Operating Data	
Maximum Operating Speed:	13 to 27 mph
Maximum Grade:	9^{o} to 42^{o}
Turn Radius:	Tangent only
Passengers	
Seated:	0 to 40
Standees:	60 to 180
Total:	60 to 180
Power Requirement:	200 to 1,750 kW

Economic Data	
Vehicle & Equipment Cost:	$3.2 to $4.2 Million/mile
Terminal/Tower Cost:	$5.9 to $9.6 Million/mile
Vehicle Life:	15 to 20 years

Notes

None.

HIGH GRADIENT TRANSIT

Gondolas

GONDOLAS

Other Names: None

Description
Gondolas are similar to aerial tramways, but employ many small cabins on a continuous cable. Although the gondola cabins can be fixed or detachable, no special turn-around facilities are required. Gondola cabins typically accommodate six to twelve passengers; thus gondola systems offer more privacy than tramways. Access for visitors with disabilities is difficult with this technology.

Characteristic	Advantages	Disadvantages
Maneuverability	- Ideal for areas with steep grades or other topographical barriers. - Can be mostly automated. - With multiple terminals, passengers can travel along multiple lines without a transfer.	- Relatively difficult to change routes and boarding in response to varying demand. - Straight-line travel only, unless multiple terminals are used.
Durability	- Moderate to long gondola cabin life.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires special operator training for safety. - Operators less available than for standard buses.
Noise	- Noise level along the cable is below the sound level of passenger cars. Noise level at the terminal stations can be insulated.	- No significant disadvantages.
Fuels	- Diesel or electric motor to drive the cable.	- No other fuel types available at this time.
Cost	- Relatively low initial/capital cost relative to rail technologies, including funiculars. - Operating cost low to moderate, relative to the number of passengers that can be served.	- High initial/capital cost relative to bus vehicles. - Requires a high cost investment in the physical system of towers, cables, and stations.
Vehicle, Parts, Service Availability	- Relatively simple maintenance. - Ready availability of suppliers.	- Requires site-specific design. - Most suppliers are not domestic.
Compatibility with Federally-Managed Sites	- Marginal impact on surface vegetation. - Does not form a barrier to wildlife or pedestrian movements. - Appearance has a higher recreational appeal than some other guideway transit systems. - Allows management of visitor movement and interpretive opportunities.	- In some remote settings, this technology may be more visually intrusive than funiculars due to the prominence of towers in certain locations. - Turnaround facilities are complicated.
Vehicle Features	- Provides excellent viewing opportunities in appropriate terrain. - More privacy/less crowding than aerial trams. - Cable can accommodate freight units interspersed with passenger cabins.	- Turnaround facilities are complicated. - Limited system length.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	5.6 to 7.8 feet
Width:	4.2 to 7.4 feet
Height:	5.8 to 8 feet
Weight:	700 to 4,100 lbs.
Power Source:	Cable propulsion
Right of Way:	
Horizontal	32 to 38 feet
Vertical	8 feet
Low Floor:	Low floor boarding by design.

Operating Data	
Maximum Operating Speed:	11 to 14 mph
Maximum Grade:	31^{o} to 46^{o}
Turn Radius:	Tangent Only
Passengers	
Seated:	4 to 24
Standees:	0 (Standees not typical.)
Total:	4 to 24
Fuel Consumption:	
Power Requirement:	200 to 1750 kW

Economic Data	
Vehicle Cost:	$25,000 to $40,000 / cabin
Station Cost	$10,000-$20,000
Towers/Equipment :	$0.4 to $0.7 Million
Estimated Life:	30 years

Notes
None.

WATERBORNE TRANSIT

INTRODUCTION TO WATERBORNE TRANSIT

Waterborne transit technologies have been devised for one of several areas with special needs or constraints that are not well served by traditional bus or rail systems. Although long and even floating bridges have been built for bus and rail technologies to cross water bodies, the demand levels are often too low or the distances across the water too great to justify such investment. It is in these circumstances that waterborne transit is most applicable. This technology category includes pontoons and skiffs, mono-hull vessels, catamarans, and hydrofoils.

Waterborne transportation systems can provide economical, fast and pleasant travel across bodies of water. A variety of marine vessel technologies currently operate worldwide. The type of vessel used depends on the type of water body, passenger capacity requirements, length of trip, depth and width of waterway, and docking requirements or accommodations. Waterborne transportation systems are generally accessible by people with disabilities via ramping (gangplanks) between the dock and the vessel. The U.S. Coast Guard establishes and enforces safety regulations for marine vessels in public service.

Technologies applicable to the National Park Service for serving passenger travel on open and protected waters include four main categories of boats. For very small numbers of passengers, pontoons and skiffs may be used. For larger volumes of passengers, mono-hull ferries, catamaran ferries, and hydrofoils are employed. Smaller versions of mono-hull ferries, catamaran ferries, and hydrofoils may also serve moderate-sized groups of passengers.

Boats are currently used in fifteen of the National Parks; examples include the Everglades in Florida, Isle Royale on Lake Superior, Glen Canyon / Lake Powell in Utah, and the Channel Islands in California. Many of these parks include coastline property and islands, while others include service to land-locked lakes. For a number of parks, boats provide the primary means of access and transportation for the visitors.

Specific advantages and disadvantages of using water transport systems in federally-managed public lands depend on the-specific conditions and the type of marine vessel used. Site considerations may include land availability, automobile access, depth and width of waterway, and cost efficiencies compared to other transportation and infrastructure systems. Marine vessels are most appropriate when a water route is more direct or more cost-effective than a land route or necessary where the primary site is not accessible by land. The level of passenger interaction and assistance on the part of the operator depends on the specific water transport system in place. Water transport systems do not typically allow the operator a high level of passenger assistance.

Data related to the physical and operating characteristics of the four types of commonly used boats are provided below. The duration of the useful life of the vessels is assumed to be relatively similar among all four categories. All categories are generally powered by on-board, internal combustion engines, although the pontoons and skiffs may be also powered by oars. The data provided below is not meant to be exhaustive but rather an overview to compare categories.

WATERBORNE TRANSIT

Pontoons and Skiffs

PONTOONS AND SKIFFS

Other Names: None

Description
Pontoons and skiffs are small boats that generally carry fewer than forty passengers. Pontoons are small square-shaped boats that float on tubes. The water does not contact the hull directly in this case. The tubes may be of various compositions including air, foam, and other materials. Skiffs are flat-bottomed, open boats with shallow drafts. Unlike pontoons, skiffs are characterized by their pointed bow, square sterns. Pontoons and skiffs may be propelled by oars, sails or motors.

Characteristic	Advantages	Disadvantages
Maneuverability	- Highly maneuverable.	- Slow to very slow operating speeds.
Durability	- No significant advantages.	- Low to moderate life span.
Operator Availability	- Ready supply of operators. - No special operating requirements for crew.	- No significant disadvantages.
Noise	- If propelled by oars, sails, or trolling motors, they can be very quiet.	- Motors, particularly of the outboard type may create objectionable sound levels.
Fuels	- Diesel, gas, or gas/oil mix.	- Little to no availability of other fuel types.
Cost	- Low initial/capital cost relative to other vessel types. - Does not require high investment for terminal facilities.	- High operating cost relative to the number of passengers that can be served.
Vehicle, Parts, Service Availability	- Ready supply of manufacturers and mechanics. - Ready supply of lease/rent/charter opportunities.	- No significant disadvantages.
Compatibility with Federally-Managed Sites	- Provides good accessibility to remote locations.	- Not effective for serving point-to-point travel.
Vehicle Features	- Good for shallow and no-wake waters. - Low deck height or seating near level with water provide good viewing opportunities. - Open air versions are common and increase the viewing opportunities.	- Low sea-going stability. - Little or no passenger protection from the elements.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	20 to 40 feet
Beam:	10 to 15 feet
Draft:	1 to 2 feet
Power Source:	Gasoline

Operating Data	
Maximum Operating Speed:	10 to 20 knots
Maximum Grade:	Not applicable.
Passengers	
Seated:	5 to 30
Standees:	10 to 20
Total:	10 to 50

Economic Data	
Vehicle Cost:	$20,000 to $60,000
Vehicle Life:	10 to 15 years

Notes
None.

WATERBORNE TRANSIT

Mono Hull Vessels

MONO HULL VESSELS

Other Names: None

Description
Mono-hull or conventional displacement vessels are the most common vessels used in boat transportation. A wide variety of sizes are available and in use in tour and shuttle-oriented applications worldwide. These vessels are constructed of steel or aluminum. Mono-hull vessels are somewhat slow and cumbersome compared to other marine vessels.

Characteristic	Advantages	Disadvantages
Maneuverability	- No significant advantages.	- Low operating speeds relative to other vessels. - Deep draft may require dredging.
Durability	- Long life span of 20 years.	- No significant disadvantages.
Operator Availability	- Ready supply of operators. - No special operating requirements for crew.	- No significant disadvantages.
Noise	- No significant advantages.	- No significant disadvantages.
Fuels	- Diesel.	- No other fuel types at this time.
Cost	- Low initial/capital cost, relative to other large vessels. - Operating cost low relative to the number of passengers that can be served.	- High cost for terminal facilities.
Vehicle, Parts, Service Availability	- Ready supply of manufacturers. - Ready supply of lease/rent/charter opportunities.	- No significant disadvantages.
Compatibility with Federally-Managed Sites	- No significant advantages.	- No significant disadvantages.
Vehicle Features	- Variety of sizes available. - Very reliable operation. - Multi-deck vessels offer good viewing opportunities. - Enclosed decks protect passengers from the elements.	- Large size creates crowding of docks.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data

Length:	75 to 175 feet
Beam:	14 to 34 feet
Draft:	4 to 8 feet
Power Source:	Diesel
Right of Way:	

Operating Data

Maximum Operating Speed:	20 to 30 knots
Maximum Grade:	Not applicable.
Passengers:	50 to 2000
Autos:	0 to 400
Fuel Consumption:	35 gallons/hour
Range:	65 to 69 hours

Economic Data

Vehicle Cost :	\$1.0 to \$15.0 Million (passengers only) \$5.0 to \$100.0 Million (passengers and autos)
Vehicle Life:	20 years

Notes
None.

WATERBORNE TRANSIT

Catamarans

CATAMARANS

Other Names: Dual Hull Vessels

Description
Catamarans are dual hull vessels with a deck between the hulls. These vessels are typically built of aluminum to reduce weight and increase speed. Catamarans are stable in rough water and offer excellent passenger service.

Characteristic	Advantages	Disadvantages
Maneuverability	- High operating speed. - Shallow draft does not require dredging.	- Width may require widening of channels.
Durability	- Long life span of 20 years.	- No significant disadvantages.
Operator Availability	- Ready supply of operators.	- No significant disadvantages.
Noise	- No significant advantages.	- No significant disadvantages.
Fuels	- Diesel.	- Little to no availability of other fuel types.
Cost	- Operating cost low to moderate, relative to the number of passengers that can be served.	- High initial/capital cost. - High cost for terminal facilities.
Vehicle, Parts, Service Availability	- No significant advantages.	- Limited number of suppliers.
Compatibility with Federally-Managed Sites	- No significant advantages.	- No significant disadvantages.
Vehicle Features	- Large deck surface. - Good sea-going stability. - Offer good viewing opportunities. - Enclosed decks protect passengers from the elements.	- Large size creates crowding of decks.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	60 to 250 feet
Beam:	18 to 40 feet
Draft:	2 to 6 feet
Power Source:	Diesel

Operating Data	
Maximum Operating Speed:	25 to 35 knots
Passengers:	40 to 400
Fuel Consumption:	35 to 45 gal/hour
Range:	20 to 22 hours (300 miles)

Economic Data	
Vehicle Cost:	$1.0 to $3.0 Million
Vehicle Life:	20 years

Notes
None.

WATERBORNE TRANSIT

Hydrofoils

HYDROFOILS

Other Names:

Description

Hydrofoils travel above the water surface on metal struts called foils. The underwater foils are operated hydraulically to lift the hull out of the water at high speed. These vessels are expensive and require deep channels. They are most useful for point-to-point, long-distance travel, where the hydrofoil's high speed can be used to its best advantage. Hydrofoils are susceptible to damage from floating debris.

Characteristic	Advantages	Disadvantages
Maneuverability	- High operating speed.	- Deep draft may require dredging. - Not operable in rough waters.
Durability	- Moderate to long life span of 10 to 15 years.	- No significant disadvantages.
Operator Availability	- No significant advantages.	- Requires specialized crew.
Noise	- No significant advantages.	- High noise levels.
Fuels	- Diesel or gasoline.	- Little to no availability of other fuel types.
Cost	- No significant advantages.	- High cost for terminal facilities.
Vehicle, Parts, Service Availability	- No significant advantages.	- Limited number of suppliers.
Compatibility with Federally-Managed Sites	- No significant advantages.	- No significant disadvantages.
Vehicle Features	- Good sea-going stability. - Enclosed cabin protects passengers from the elements.	- Poor visibility from interior due to hull spray and incline. - Submerged foils prone to damage.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	40 to 120 feet
Beam:	15 to 50 feet
Draft:	
Foil-borne	4 to 8 feet
Foils Submerged	6.5 to 12 feet
Power Source:	Diesel or gasoline

Operating Data	
Maximum Operating Speed:	30 to 50 knots
Passengers	50 to 200
Fuel Consumption:	50 to 500 gallons/hour
Range:	2 to 5 hours

Economic Data	
Vehicle Cost:	$5 to $15 Million
Vehicle Life:	10 to 15 years

Notes

None.

GROUP SNOW TRANSIT

INTRODUCTION TO GROUP SNOW TRANSIT

Snow transit technologies have been devised for one of several areas with special needs or constraints that are not well served by traditional bus or rail systems. Although snow removal equipment and techniques have made it possible to extend bus transit and fixed guideway transit technologies into mountainous areas, the demand levels are often too low and the snow depths too great to justify such investment. In other circumstances, the remote character of the setting would be impacted if snow were to be removed or permanent facilities were constructed. It is in these circumstances that snow transit is most applicable. This technology category includes snow coaches and snow buses.

Snow transit vehicles are those specifically designed or retrofitted to allow the vehicle to travel on the surface of potentially deep snow pack without becoming stuck. This requires vehicles to have weight distribution over a much larger surface area than standard bus transit vehicles. These vehicles are manually operated and are self-propelled by an on-board engine and power source. Snow transit vehicles typically allow for a moderate level of passenger interaction and assistance on the part of the operator.

Snow transit vehicles have three major advantages.

- First, they are inexpensive, in that they do not require investment in the construction of any infrastructure since they travel over the snow.
- Second, they offer unequaled routing flexibility. Because they are not tied to a fixed guideway, they can easily be re-routed to respond to varying demand and can cover broad areas of demand.
- Third, snow transit vehicles can serve a wide range of passenger demand levels by using small to very large vehicles.

Snow transit vehicles have some disadvantages that make them unsuitable for most uses other than travelling over snow.

- First, because of their highly specialized design, they are not suitable for use on “normal” roads during the off season. Also because of their specialization, there is little opportunity for temporary use/ownership in lease, rent, or charter arrangements, relative to bus transit in general.
- Second, because most snow transit vehicles are currently powered by diesel engines, noise levels and the emission of pollutants may be objectionable in remote, natural settings.
- Third, they are capable of serving only low to moderate passenger loads.

Two vehicle types are discussed below. The snow coach is the smaller of the two vehicle types. It is fitted with tank-style tracks, rather than wheels. The snow bus carries more passengers and rides on over-size rubber tires that distribute its weight.

GROUP SNOW TRANSIT

Snow Coaches

SNOW COACHES

Other Names: Passenger Snow Cats, Cat-Converted Vans

Description

Snow coaches provide a cost-effective means for accessing remote, snow-covered or rugged terrain not easily served by other vehicle technologies. The snow coach is most useful for low passenger demand on short to moderate length trips. These vehicles are best suited to point-to-point travel with a minimum amount of passenger boarding/alighting. These vehicles are either specifically designed as snow coaches (i.e. passenger snow cats) or are standard vans with a cat-track conversion. The snow coaches can be single units or can tow an additional unit. The tracks can be made of metal and/or rubber.

Characteristic	Advantages	Disadvantages
Maneuverability	- Highly maneuverable on snow with short turning radius. - Very stable even over rough terrain or steep slopes.	- Slow if used on standard roads.
Durability	- No significant advantages.	- Low to moderate life span of 10 to 12 years. - High level of maintenance required on tracks.
Operator Availability	- Ready availability of operators.	- Requires special training for safety.
Noise	- No significant advantages.	- Noise from internal combustion engine may be objectionable.
Fuels	- Diesel or gasoline typical. - Alternate fuels available for van conversions.	- No significant disadvantages.
Cost	- Low cost relative to standard transit buses.	- No significant disadvantages.
Vehicle, Parts, Service Availability	- Wide number of suppliers of vans for conversion. - Wide availability of engine mechanics.	- Limited number of suppliers of snow coaches and conversion track parts relative to std. buses. - Relatively lower availability of track mechanics.
Compatibility with Federally-Managed Sites	- Low weight transfer to ground (per sq. ft.) enables travel over snow or sensitive terrain. - Travel over snow allows accessibility into remote areas without permanent investment in infrastructure or associated environmental impacts.	- No significant disadvantages.
Vehicle Features	- No significant advantages.	- Steering difficult on hardpack or ice.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	10 to 18 feet (single unit)
Width:	8.0 to 9.0 feet
Height:	8.0 to 10.0 feet
Weight:	6,500 to 15,000 pounds
Power Source:	Diesel or gasoline
Low Floor:	Not typically available

Operating Data	
Maximum Operating Speed:	20 to 40 mph (snow)
Maximum Grade:	25° = 47% (snow)
Turn Radius:	25 to 30 feet
Passengers	
Seated:	8 to 16
Standees:	Not typical
Total:	8 to 16
Fuel Consumption:	2.0 to 5.0 mpg

Economic Data	
Vehicle Cost:	$70,000 to $210,000
Vehicle Life:	10 to 12 years

Notes

If tracks are rubber, there is more utility and maneuverability in no-snow (dry pavement) conditions.

GROUP SNOW TRANSIT

Snow Buses

SNOW BUSES

Other Names: Tundra Buggy

Description

Snow buses provide a cost-effective means for accessing remote, snow-covered or rugged terrain not easily served by other vehicle technologies. The snow coach is most useful for low to moderate passenger demand on short to moderate length trips. These vehicles are best suited to point-to-point travel with a minimum amount of passenger boarding/alighting due to their single-door, high-floor design. These vehicles use over-sized tires to distribute the weight of the vehicle.

Characteristic	Advantages	Disadvantages
Maneuverability	- Maneuverable on snow and other off-road conditions.	- Not generally usable on standard roads. - Slow maximum operating speed.
Durability	- Can have highly durable interiors.	- Shorter life span than transit buses.
Operator Availability	- Ready supply of operators.	- No significant disadvantages.
Noise	- No significant advantages.	- Internal combustion engine may produce objectionable volume noise.
Fuels	- Typically available in diesel.	- Little to no availability in alternate fuels.
Cost	- No significant advantages.	- No significant disadvantages.
Vehicle, Parts, Service Availability	- No significant advantages.	- Limited number of suppliers and mechanics. - Used models and lease/rent/charter opportunities less available than for other vehicles.
Compatibility with Federally-Managed Sites	- Low weight transfer to ground (per sq. ft.) enables travel over snow or sensitive terrain. - Appearance may have more novelty/visitor appeal than smaller-capacity 4x4's. - Travel over snow allows accessibility into remote areas without permanent investment in infrastructure or associated environmental impacts.	- Large size may be incompatible with some parks and remote areas.
Vehicle Features	- High passenger capacity for its intended use.	- More mechanically complex than std. buses.
Other	- No significant advantages.	- No significant disadvantages.

Physical Data	
Length:	45 to 50 feet
Width:	11 to 12 feet
Height:	12.5 to 14.0 feet
Weight:	45,000 to 55,000 pounds
Power Source:	Diesel
Low Floor:	Not available.

Operating Data	
Maximum Operating Speed:	25 to 30 mph
Maximum Grade:	50%
Turn Radius:	55 to 75 feet
Passengers	
Seated:	40 to 56
Standees:	Not typical
Total:	40 to 56
Fuel Consumption:	3 to 5 mpg.

Economic Data	
Vehicle Cost:	$420,000 to $670,000
Vehicle Life:	10 to 15 years

Notes

None.

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Introduction to Appendices
for
Candidate Vehicle Technologies for Alternative Transportation Systems

This document contains three appendices to the *Candidate Vehicle Technologies for Alternative Transportation Systems (ATS) in National Parks and Related Federally-managed Lands*. That report identifies and describes over 30 mass transit vehicle technologies in five modal categories – bus, rail/guided, high gradient, water, and snow – with potential applicability in National Parks and related federally-managed lands. These appendices cover the following topics.

- Appendix A - Alternative Fuels and Propulsion – Provides a description of the types of fuel and propulsion systems that are alternatives to conventional gasoline and diesel engines for transportation. Includes ideas on the pros and cons of each fuel/system type as well as the potential applicability to the range of vehicles.

- Appendix B – Intelligent Transportation Systems (ITS) – This appendix provides an overview of how advanced information processing, information transport and communications, and information display technology can improve transit system operations and transit customer convenience via real-time system tracking and management.

- Appendix C – Vehicle Manufacturers – Provides a list of manufacturers by vehicle technology category along with web sites where available.

The first two appendices provide an added dimension of information with relevance to the basic vehicle technology data presented in the Candidate Vehicle Technologies report as these two topics have a high degree of applicability in the National Parks and related public lands. The third appendix provides a helpful starting point for further research into the vehicles of particular manufacturers.

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APPENDIX A

Alternative Fuels and Propulsion

Introduction

This appendix provides descriptions of alternative fuels and propulsion systems as well as advanced emissions control systems for conventionally fueled vehicles available for use at federally-managed land sites. Conventionally fueled vehicles are standard gasoline- and diesel-fueled vehicles. Alternative fuel and low-emission vehicles include electric drivetrain vehicles as well as natural gas, propane, biodiesel, and alcohol fuels as described in Table A-1, which is located at the end of the text.

These vehicle and fuel descriptions are intended to provide a quick reference and starting point for investigating the purchase and implementation of low-emission vehicles at federally-managed land sites. Purchasing of any alternative fuel vehicles should be a part of an overall transportation planning effort performed by the federally-managed land site, as described in the planning guidebook.

This appendix describes alternative fuels and low-emission technology vehicles in several subsections as follows:

- Why Consider Alternative Propulsion Systems – an overview of why alternative propulsion. systems and low-emission vehicles are important to consider for visitor and other transportation at federally-managed land sites.
- Selecting Alternative Fuels – information is provided regarding evaluation of various alternative fuels options.
- Alternative Fuel and Low-Emission Vehicle Propulsion Technologies – describes alternative fuel and low-emission technologies.
- Alternative Fuels Used At Federally-managed Land Sites – examples of other alternative fuel projects in parks and federally-managed lands.
- Sources of Alternative Fuel Vehicle Technology Information –publications, references, and Internet web addresses of useful sites containing information on alternative fuel vehicles.

Why Consider Alternative Propulsion Systems

Concern for the environment and air quality, more stringent exhaust emissions standards, and growing dependency on imported petroleum were principal drivers for use of alternative fuels and propulsion systems. Alternative fuels use, in most applications, is more expensive than conventional fuel use. The economics of alternative fuel use has been steadily improving with wider implementation, expanding beyond niche applications where the economics can be advantageous. The potential for lower exhaust emissions, desire for a "green image", and lower noise levels of vehicles with electric drive technologies, as compared to conventional vehicles, can offset the extra cost of vehicles, fuel, or infrastructure changes.

Several important laws have encouraged use of alternative fuels, in particular, the Clean Air Act Amendments (CAAA) of 1990, the Energy Policy Act (EPAct) of 1992, and the Alternative Motor Fuels Act (AMFA) of 1988 and various executive orders. These acts have been focused on the viability of alternative fuels as replacements for conventional fuel (diesel and gasoline), the reduction of imported petroleum usage for energy security concerns, and the reduction of /vehicle emissions. Clean or low-emissions technologies are often discussed in terms of the full life-cycle emissions of the fuel and vehicle technology. Life-cycle emissions include the fuel production, formulation/preparation, distribution, and dispensing as well as the vehicle emissions from the tail pipe and on-board fuel system (evaporative emissions). Life-cycle emissions are important to remember when considering greenhouse gas emissions (includes carbon dioxide and methane).

Both the CAAA (Clean Fuel Fleet Programs) and EPAct require light-duty fleets in the federal and state government, municipal, fuel providers, and private fleets to make a portion of their new vehicle purchases alternative fuel powered. EPAct allows the purchase of heavy-duty alternative fuel vehicles to substitute for the purchase of several light-duty vehicles. There also are Presidential Orders and local incentive programs that promote the use of alternative fuels and low-emission vehicles in fleets. There are currently no Federal fleet mandates for the use of alternative fuels in heavy-duty fleets.

Driving factors for considering low-emission vehicle technologies at federally-managed land sites are the public expectations of cleaner air and an environmentally friendly experience. The National Park Service, the Bureau of Land Management, and the U.S. Fish and Wildlife Service, with their environmental stewardship role and the clean technology mandate of the Department of Interior, are expected to be leaders in this area.

Selecting Alternative Fuels

Selecting alternative fuels and low-emission technology vehicles for use at a particular federally-managed land site involves consideration of many factors. Each site has unique transportation needs and operating environment. Questions to consider at the start of planning for alternative fuel vehicles are:

1. What are the transportation needs (daily ridership, heating or air conditioning of buses, etc.) within the federally-managed land site?
2. Which vehicles is the federal land site considering adding or replacing in the next year or two (this should include more than just visitor transportation); what vehicles will be added or replaced in the next five years?
3. What vehicles are available in the class range (light duty, heavy duty) and application needed?
4. What is the budget for vehicles and infrastructure at the federally-managed land site?
5. Which alternative fuels and technologies are readily available near the federal land site? Are there existing refueling stations available nearby with alternative fuels available? Will a "fuel supplier" provide an alternative fuel station that is convenient and economical for on-site vehicle use?
6. Are the technologies being considered suitable for the intended operating environment?
7. Are the fleet managers, including drivers, supervisors and maintenance staff dedicated to implementing the technology?

Each fuel and technology has its advantages and disadvantages that will need to be considered. One fuel may not satisfy all needs and, in some cases, it may be necessary to consider using different fuels for different classes of vehicles (light-duty, heavy-duty). Furthermore, alternate fuels and advanced propulsion technologies have some additional safety issues that must be considered in planning for vehicle purchases, infrastructure modification, and construction. Table A-2, at the end of the text, shows some advantages and disadvantages of each technology being considered in this section.

Vehicle requirements should be defined for each potential alternative fuel and low-emission technology application. This includes consideration of purchase and operating costs of vehicles/technologies and refueling.

Issues to be considered in the selection of vehicles and technologies include the following:

- Vehicle purchase from original equipment manufacturer (OEM) or re-powering an existing vehicle and adding appropriate on-board fuel storage.
- Expected duty cycle of the vehicles to be added or replaced; this would include range requirements, average speed, and type of terrain.
- Initial and operating cost of conventional and alternative fuel vehicles for comparisons
- Infrastructure requirements for refueling, storage of vehicles, and maintenance of vehicles; safety is a key factor here.
- Investigation of incentives to offset the cost of the vehicles, infrastructure, and upgrade of facilities; these incentives could come from federally-managed land sites, Department of the Interior, other federal funding, state and local government groups, or from alternative fuel suppliers.
- Availability of warranty service and support of the new vehicles and technologies. Many of the federally-managed land sites are in remote areas and may have a difficult time getting the support that they need.
- There may be other special issues to investigate, such as the ability of the roads to withstand the increased weight of some alternative fuel vehicles, coordination with the local communities and coordination with other federally-managed land sites to standardize purchases to reduce vehicle costs.

At each step of the selection process, it is important to access accurate, reliable information on each technology under consideration and to consult with experienced users and experts. An expert consultant with experience in designing and implementing alternative fuel fleets may provide useful insights and help. Champions for the project at the federally-managed land site will also contribute to a successful implementation. These champions should have the ability to allocate resources for problem solving and have interest in learning about the new technologies in order to become an in-house expert.

Alternative Fuel and Low-Emission Vehicle Propulsion Technologies

Conventional Fuel Modifications

Traditional highway fuels, both gasoline and diesel, are undergoing modifications to make them more acceptable for modern, cleaner burning engines. Several fuel modifications have been phased-in during the past five years and in many cases, allow engine manufacturers to produce engines that have significantly lower emissions levels.

Clean Diesel

Reduction of sulfur in diesel fuel has allowed the diesel engine to operate with lower particulate emissions (PM). Highway diesel fuel is now available with 0.05% sulfur content and allows heavy-duty (HD) truck engines to achieve a PM emission level of 0.10 g/bhp-hr (0.05 for buses). Even lower sulfur content (30 parts per million or lower) in diesel fuel is being discussed and should allow additional improvements.

New diesel engine fuels are also being developed that allow even cleaner diesel engine operation. The current potential fuels include: Reformulated diesel (much like reformulated gasoline), Di-methyl ether, Fischer-Tropsch diesel, diesel/water emulsions, and naphtha/water emulsions. Both major petroleum suppliers and heavy-duty engine manufacturers are experimenting with these new fuels to determine air quality benefits.

Reformulated Gasoline (RFG):

Various states and regions faced with air quality problem use reformulated gasoline. RFG programs have the ability to locally reduce the carbon monoxide and formaldehyde levels in the air. The RFG is a specially refined gasoline with lower vapor pressure, lower aromatics, and frequently contains a fuel "additive" that increases the amount of oxygen in the fuel. Popular additives used recently have been MTBE (methyl tertiary-butyl ether), ETBE, TAME, ethanol, methanol, and tertiary-butyl alcohol.

Use of MTBE is in the process of being phased out because of releases of MTBE into the country's water supplies. The levels of MTBE in potable water are increasing above suggested levels. Remediation of abandoned underground storage tank (UST) sites, phase-out of two-cycle marine engines, and other steps have been undertaken to resolve this potential health problem.

<u>Vehicle & Engine Availability of Various Alternative Fuels</u>

Natural Gas

Natural gas is being used successfully in a variety of heavy-duty and light-duty vehicles. The fuel is available both in gaseous and liquid forms. In gaseous form, it is called compressed natural gas (CNG) and is carried in high-pressure tanks (3,600 psi). As a liquid, it is call liquefied natural gas (LNG) and is carried in insulated, low-pressure cryogenic tanks (60-150 psi, -260 to -150F). LNG is more energy dense than CNG and, therefore, requires less fuel tank volume and weight than CNG. Both CNG and LNG entail some energy efficiency penalty. Typically, LNG is preferred for heavy-duty vehicles while CNG is preferred in lighter duty vehicles. However, CNG is commonly used in full size transit buses because they can accommodate the large and heavy CNG fuel tanks. LNG is used almost exclusively in heavy-duty trucks, but is also used in a few full-size transit buses.

A natural gas engine can normally operate with either a CNG or LNG fuel system. The heavy-duty engine manufacturers are well up the "learning-curve" for this alternative fuel and offer a wide variety of products with ratings from less than 200 to more than 400 horsepower. Light-duty CNG passenger cars, vans, and pickup trucks are offered by all major auto manufacturers. Several of these light-duty vehicles are offered in a "bifuel" configuration - this allows the vehicle to be operated on either CNG or gasoline. However, these bifuel configurations are typically less efficient and have higher emissions than dedicated natural gas vehicles. Use of both CNG and LNG also requires fueling infrastructure to store and dispense the fuel, and facility modification to ensure safe operation.

Alcohol Fuels

Both methanol and ethanol have been used in the heavy-duty and light-duty transportation markets. In heavy-duty applications, it was determined that both alcohol fuels could be used in "neat" (100% pure) form and would operate in high efficiency diesel engines. Although initially interest was high, these heavy-duty engines suffered significant reliability and durability problems and the fleet operators were disappointed in the engine's resulting life-cycle costs. No heavy-duty engine manufacturer currently offers product that can utilize either alcohol fuel.

In light-duty applications, both ethanol and methanol were blended with 15% gasoline and used in spark ignition engines. These vehicles are referred to as "flex fuel" vehicles and can operate on any available mixture of all gasoline and all alcohol blends (up to 85% by volume). "Flex fuel" suppliers include both Ford Motor Company, which offers a passenger car, and Daimler/Chrysler, which offers a van, that operates on E85 (85% ethanol + 15% gasoline). M85, a mixture of 85% methanol and 15% gasoline, is still available from a number of filling stations in California although no automobile manufacturer yet produces a compatible vehicle.

Propane (HD-5)

Propane is currently the most widely used alternative fuel in this country. Medium- and heavy-duty trucks are available from both Ford and Freightliner that can operate on propane. Ford also allows conversion (with full factory warranty) of certain gasoline powered vehicles to propane fuel if the conversion work is performed by a Ford authorized QVM (Qualified Vehicle Modifier). No propane-powered engine for use in full-size transit buses is currently offered.

Heavy-duty engine suppliers, Cummins and DDC (Detroit Diesel Corp), have been developing some products that can operate on propane. Cummins currently offers their B5.9LPG engine that is EPA certified with propane fuel.

Biodiesel (B20 & B100)

B20 (20% biodiesel and 80% petroleum diesel) does not require engine modifications or purchase of special vehicles to utilize the fuel. However, only modest improvements in exhaust emissions have been reported with minor changes in engine timing. B20 biodiesel fuel is compatible in any diesel engine. On-going demonstrations in some states are currently validating acceptance of B20 fuel in limited heavy-duty applications.

Neat biodiesel (B100, i.e. 100% biodiesel) may also be used in diesel powered vehicles without modifications and is considered an alternative fuel by EPAct (Energy Policy Act). Because of cold weather filter plugging problems and high fuel cost (~ $4.00 per gallon), no current demonstrations of this fuel are known. However, B100 fuel could be used in southern-tier states, where the temperatures typically do not fall below 40 degrees F, the temperature at which vehicle fuel filter plugging has been observed.

Electric Drivetrain Technology

<u>Batteries</u> - Battery-powered vehicles are used successfully in both light and heavy-duty vehicles, mostly in niche applications. Two major automotive manufacturers offer battery powered light-duty trucks. Both GM and Ford have light-duty pickup trucks available powered by lead-acid batteries that offer operating ranges of 40 to 60 miles between recharging. Several medium-duty buses are also being manufactured that use various battery technologies.

Major improvements in the quantity of energy stored in batteries are being addressed by a joint industry/government program that is entitled the USABC (United Stated Advanced Battery Consortium). This consortium has funded research and development activities related to advanced vehicular batteries. Progress to date in achieving program goals has been disappointing, but several unique/improved batteries have been developed.

Fuel Cells - Because current storage batteries have limited energy storage capacity, manufacturers have embarked on several paths that explore alternative methods of providing electric power to an electric motor - which drives the vehicle. Several companies and consortiums are developing fuel cells that can transform gaseous hydrogen directly into electricity. The hydrogen for the fuel cell can be carried as a compressed gas (but provides limited range) or as a hydrocarbon fuel (i.e.: gasoline, methanol, propane or natural gas). A small, on-board chemical plant (reformer) is used to strip the hydrogen from the hydrocarbon fuel, resulting in gaseous hydrogen for the fuel cell and improved fuel storage (range) for the vehicle. Programs are in very early stages of development and commercially available vehicles are not anticipated in the next five years.

Hybrid Electric - This technology combines a heat engine (small diesel, gasoline, natural gas, or propane engine) with an electric generator, and an electric drive motor. The internal combustion engine drives the electric generator, which powers the electric motor that propels the vehicle. The technology also traditionally uses intermediate storage devices (such as batteries or capacitors) to allow energy recovery from vehicle braking. Hybrid electric configuration allows greatly increased efficiency and lower emissions without costly infrastructure modifications. Several demonstration programs are currently underway for heavy-duty vehicles including buses with emissions levels comparable to CNG buses. Light duty vehicles are emerging in commercial availability.

Alternative Fuels Used At Federally-managed Land Sites

Examples of some alternative fuels/propulsion transportation currently in use at federally-managed land sites include the following:

Scotts Bluff National Monument - Biodiesel (B20) used in a 15 passenger van to transport visitors around the monument.

Mammoth Caves National Park - Developing infrastructure and facilities for ethanol (E85) use in park vehicles.

Yellowstone National Park - A 1995 Dodge Pickup "Truck-in-the-Park" program with a Cummins 5.9 liter diesel vehicle was operated for about a year and obtained 26,000 miles using B100 (neat) biodiesel fuel. Opacity of the exhaust was reduced by 50%. An identical Dodge vehicle and engine was tested using biodiesel for 4 years (100,000 miles) by the University of Missouri-Columbia and was analyzed by Cummins after the test. It showed that internal parts were exceptionally clean with minimal wear.

Grand Canyon National Park – natural gas and electric transit vehicles.

Zion National Park, Acadia National Park, and Lyndon Johnson National Historic Park –propane vehicles.

Cape Cod National Seashore – electric trams used for visitor transportation.

Table A-1: Alternative Fuels and Low-Emission Vehicle Technologies

Alternative Fuel or Technology	Description
Natural Gas	Natural gas is found in abundant supplies in the United States. It is a gaseous mixture, composed primarily of methane (usually 90 percent or more) and other hydrocarbon gases such as ethane, propane, butane, and pentane.
• Compressed Natural Gas (CNG)	CNG is usually stored on-board at high pressure (either 3,000 psi or 3,600 psi maximum service pressure) for storage and then dispensed for vehicle usage. The fuel is stored in several high-pressure cylinders on the vehicle. Cylinders vary in weight, size and composition and can be made of steel or aluminum, or may have a steel, aluminum or plastic liner reinforced with carbon or glass fiber composite.
• Liquefied Natural Gas (LNG)	LNG is a cryogenic liquid stored in a vacuum-insulated tank that is usually a double-walled stainless steel construction. LNG is stored on-board a vehicle at 70 psi to 150 psi. This liquid fuel is vaporized (heated) into a gaseous state before entering the engine's fuel management system.
Propane (LPG, HD-5)	This fuel is also called liquefied petroleum gas (LPG), which consists primarily of propane and may have a significant amount of butane. HD-5 is the current propane fuel specification for on-road vehicles, referring to a fuel that has less than 5% propylene or butane content. The fuel is stored on-board the vehicle in single wall, uninsulated, 250 psi rated fuel tanks.
Biodiesel (neat, B20)	Biodiesel can be produced from any plant- or animal-derived oil product. This fuel can be used in the 100 percent biodiesel form (or neat) or be blended with diesel fuel (usually 20 percent biodiesel and 80 percent diesel, which makes up B20). Biodiesel and biodiesel blends can be stored in standard diesel tanks.
Alcohol	Alcohol is usually produced from agricultural products and waste products. Alcohol can also be made from natural gas and coal.
• Methanol (neat, M85)	Methanol is an alcohol produced primarily from natural gas. Because it also can be derived from biomass or coal, the domestic resource base for methanol is vast. Methanol fuel for vehicles can be 100 percent (or neat) or 85 percent methanol and 15 percent gasoline. Standard gasoline and diesel tanks can be used. Diesel engines can be modified to use M100 while M85 is typically used in light-duty, spark ignition engines.
• Ethanol (E95, E85)	Ethanol is an alcohol derived from biomass (corn, sugar cane, grasses, trees, and agricultural waste). Ethanol blends are usually composed of 95 percent ethanol and 5 percent gasoline, methanol, or a combination (E95). The five-percent gasoline and/or methanol are used to de-nature the ethanol, that is, to make it unsuitable for human consumption. Standard gasoline and diesel tanks can be used. Diesel engines can be modified to use E100 while E85 is typically used in spark ignition engines.

Table A-1: Alternative Fuels and Low-Emission Vehicle Technologies (continued)

Electric Drivetrain	Many new and future vehicle designs are incorporating electric drivetrain components such as electric drive motors and the ability to recover energy through regenerative braking (recover mechanical energy by converting it to electricity through the braking process). Electric drivetrain vehicles allow the usage of lower emissions technologies such as batteries and fuel cells.
• Battery Only	A battery only vehicle has an electric motor drivetrain with only batteries to provide power to the wheels of the vehicle.
• Hybrid	A hybrid-electric vehicle incorporates an electric motor drivetrain, batteries (or possibly capacitors or a flywheel) as an electric energy storage device, and an external power source (prime mover), such as an internal combustion engine or fuel cell.
• Fuel Cell	A fuel cell powered vehicle has an electric motor drivetrain and a fuel cell, which converts hydrogen and air to electricity to provide power to the wheels. The fuel cell powered vehicle may also include batteries for energy storage. The fuel cell needs an on-board source of hydrogen either stored as hydrogen or from a reformer using another fuel such as natural gas, methanol, propane or gasoline. These vehicles are in the developmental and early demonstration stage.
Low Sulfur Diesel and Gasoline with Advanced Catalysts and Filters	Gasoline and diesel fuels have a significant amount of sulfur in them. The sulfur in the fuel reduces the ability of a catalyst to reduce emissions products into more environmentally friendly components and contributes to the particulate emissions (PM) of the engine. With the sulfur content of diesel and gasoline fuels reduced significantly, more active catalysts in conjunction with a particulate filter can be used to significantly reduce emissions (some have suggested as low as current natural gas engine emissions levels).
Other Fuels	There are several other fuels under development with the potential to reduce emissions and the use of imported petroleum. These other fuels include p-series fuels (combination of renewable and fossil fuel), di-methyl ether (DME), diesel fuel produced from methane/natural gas through the Fischer-Tropsch process, water-emulsion fuels, and others.

Table A-2: Alternative Fuels – Advantages & Disadvantages Compared to Conventional Fuels

Alternative Fuel or Technology	Advantage	Disadvantage
CNG	Fuel can be less costly than traditional diesel or gasoline. Many vehicle types are available from OEMs and converters. Emissions are low, in some cases, much lower than diesel fuel vehicles.	Fuel storage causes significant increase in vehicle weight. Vehicle incremental cost is 15 to 20% and higher than diesel. Fueling infrastructure is costly. Operating range issue.
LNG	Lower vehicle fuel storage volume and weight than CNG for the same amount of fuel. Same fuel cost as traditional fuels. Emissions are low, in some cases, much lower than diesel fuel vehicles.	Vehicle incremental cost is 15 to 20% and higher than diesel. Fueling infrastructure costly and must be trucked from a limited number of sources. Operating range issue.
Propane	Available as highway fuel in most regions. Customer's recognition of fuel properties. Easily stored and relatively inexpensive (when compared to other alternative fuels). Emissions are low, but not as low as natural gas vehicles.	Slightly higher vehicle costs than conventional vehicles. Fueling infrastructure required. Not available for all vehicles.
Biodiesel	No modifications needed to diesel vehicles or fueling station. This is a renewable fuel with low life-cycle emissions. However, most heavy-duty applications use B20, or only 20 percent biodiesel with diesel. Some emissions benefits, especially in particulate matter.	Fuel more expensive than traditional diesel. B20 not considered an alternative fuel, but credits available for use. In cold climates, fuel clouds at a higher temperature than diesel fuel. Minimal, or no emissions improvement, particularly NO_x.
Methanol (M85 or M100)	Alternative fuel that satisfies EPAct. Some emissions benefits.	Expensive fuel not available in many states. Fuel may degrade some plastic and rubber components. Not available for heavy-duty engines.
Ethanol (E85 or E100)	Alternative fuel that satisfies EPAct. This fuel is considered completely renewable. Has low life-cycle emissions.	Expensive fuel not available in many states. Fuel may degrade some plastic and rubber components.
Battery	Zero emission vehicle. Quiet operation. Range issue can be minimized with use of fast or opportunity charging.	Range limited. Charging infrastructure required.
Hybrid Electric	Greatly improved efficiency. Lower, but not zero engine emissions. If diesel or gasoline hybrid, no costly fueling infrastructure required.	Limited operational experience. Expensive initial vehicle cost. Battery life unknown.
Fuel Cell	Replaces conventional engines. Very low emissions. Uses hydrogen, or other fuels reformed on-board to get hydrogen.	Not currently available except in demonstration vehicles. Very costly technology. Reformer needed to make hydrogen from hydrocarbon fuels or an infrastructure to provide hydrogen fueling.

Sources of Alternative Fuel Vehicle Technology Information

References for more detailed information on alternative fuels and propulsion for vehicles and infrastructure:

1. The National Park Service Transportation Planning Guidebook, National Park Service, September 1999, http://www.nps.gov/transportation/alt/guidebook/index.htm

2. Use of Alternative Fuels in Transit Buses, GAO, Washington, DC 20548, December 1999, GAO/RCED-00-18

3. Guidebook for Evaluating, Selecting, and Implementing Fuel Choices for Transit Bus Operations, Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418, 1998, TCRP Report 38

4. Alternative Fuel Transit Buses, Final Results from the National Renewable Energy Laboratory (NREL) Vehicle Evaluation Program, NREL, 1617 Cole Boulevard, Golden, CO 80401, October 1996, NREL/TP-425-20513

5. Design Guidelines for Bus Transit Systems Using Alcohol Fuel (Methanol and Ethanol) as an Alternative Fuel, U.S. Department of Transportation, Federal Transit Administration, Office of Technology, 400 Seventh Street, S.W., Washington DC 20590, August 1996, DOT-FTA-MA-26-7021-96-3

6. Design Guidelines for Bus Transit Systems Using Compressed Natural Gas as an Alternative Fuel, U.S. Department of Transportation, Federal Transit Administration, Office of Technology, 400 Seventh Street, S.W., Washington DC 20590, June 1996, DOT-FTA-MA-26-7021-96-1

7. Design Guidelines for Bus Transit Systems Using Liquefied Natural Gas (LNG) as an Alternative Fuel, U.S. Department of Transportation, Federal Transit Administration, Office of Technology, 400 Seventh Street, S.W., Washington DC 20590, March 1997, DOT-FTA-MA-26-7021-97-1

8. Design Guidelines for Bus Transit Systems Using Liquefied Petroleum Gas (LPG) as an Alternative Fuel, U.S. Department of Transportation, Federal Transit Administration, Office of Technology, 400 Seventh Street, S.W., Washington DC 20590, September 1996, DOT-FTA-MA-26-7021-96-4

9. Liquefied Natural Gas Safety in Transit Operations, U.S. Department of Transportation, Federal Transit Administration, Office of Technology, 400 Seventh Street, S.W., Washington DC 20590, March 1996, DOT-FTA-MA-20-7007-95-3

10. Summary Assessment of the Safety, Health, Environmental and System Risks of Alternative Fuel, U.S. Department of Transportation, Federal Transit Administration, Office of Technology, 400 Seventh Street, S.W., Washington DC 20590, and U.S. Department of Energy, Forrestal, 1000 Independence Ave., Washington DC 20585, August 1995, DOT-FTA-MA-90-7007-95-1

11. Compressed Natural Gas Safety in Transit Operations, U.S. Department of Transportation, Federal Transit Administration, Office of Technology, 400 Seventh Street, S.W., Washington DC 20590

12. Ground Transportation for the 21st Century. National Conference of State Legislatures and American Society of Mechanical Engineers. August 1999. NCSL 1560 Broadway, Denver, CO 80202

13. Alternative Fuels Guidebook: Properties, Storage, Dispensing and Vehicle Facility Modifications. Richard L. Bechtold, P.E. 1997. Society of Automotive Engineers, Inc. 400 Commonwealth Dr. Warrendale, PA 15096.

Fuel Advocacy Groups

1. Propane Vehicle Resource Guide, RR Publishing, Inc., 1580 Logan St., Suite 755, Denver, CO 80203, (303) 863-0521, http://www.rppublishing.com

2. NGV Resource Guide, RP Publishing, Inc., 1580 Logan St., Suite 755, Denver, CO, 80203, (303) 863-0521, http://www.rppublishing.com

3. EVs for Work and Play, Electric Vehicle Association of the Americas, 701 Pennsylvania Avenue, N.W., Fourth Floor, Washington, D.C. 20004, (202) 508-5995, http://www.evaa.org

4. Biodiesel Report, "The news source for the Biodiesel Industry", P.O. Box 104898, Jefferson City, MO 65110-4898

Internet Web Sites

Several web sites useful for the investigation of alternative fuel vehicles are given below:

General

Transit Cooperative Research Program
Transportation Research Board
http://www.nas.edu/trb/index.html
U.S. General Services Administration
http://www.gsa.gov
This site contains information on the alternative fuel fleets purchased by the U.S. Government.

DOE/Alternative Fuel Data Center
http://www.afdc.doe.gov/altfuels.html
General description and fuel supply information on the major types of alternative fuels can be found on this site. There is also information addressing training and safety issues when operating alternative fuel vehicles.

EPA Office of Mobile Sources
http://www.epa.gov/omswww
This site has information about emissions, regulations, and market incentives for alternative fuel vehicles.

Railroad Commission of Texas
http://www.rrc.state.tx.us/divisions/afred/afrd.html
This site provides information on the Alternative Fuels Research and Education Division (AFRED) of the Texas Railroad Commission.

West Virginia University Department of Mechanical and Aerospace Engineering
http://www.cemr.wvu.edu/~wwwatf/index.html
An overview of alternative fuel research activities at West Virginia University is found at this site.

California Energy Commission
http://www.energy.ca.gov/afvs/ABCsintro.html
This site contains a link to a guide to alternative fuel vehicles.

U.S. Department of Energy, Office of Transportation Technologies
http://www.ott.doe.gov/programs.shtml
This site contains a list of links to current U.S. Office of Transportation Technologies alternative fuel programs.

Energy Information Administration
http://www.eia.doe.gov
This site provide statistics on alternative fuel vehicle usage and alternative fuel usage.

American Public Transportation Association
http://www.apta.com
This site provides information on the transit industry.

National Association of Fleet Administrators, Inc
http://www.nafa.org/public/altfuelsidx.html
This site provides information on the laws and regulations addressing alternative fuel use.

DOE Alternative Fuel Vehicle Fleet Buyer's Guide
http://www.fleets.doe.gov/
This site has a searchable database of currently manufactured alternative fuel vehicles.

<u>Engine and Vehicle Manufacturers</u>

Gillig
http:/www.gillig.com
- alternate fuel buses

Neoplan USA
http:/www.neoplan.de
- alternate fuel buses

Cummins Engine Co.
http://www.cummins.com/bus/altfuels.html
- natural gas and propane engines

Detroit Diesel Corp.
http://www.detroitdiesel.com
- diesel and natural gas engines

Deere Power Systems
http://www.deere.com
- natural gas engines

Mack Trucks
http://www.macktrucks.com/product/vision/index.html
- natural gas trucks and engines

Freightliner Corporation
http://www.freightliner.com/
- trucks

Blue Bird Corp.
http://www.blue-bird.com
- school and transit buses

E Bus
http://www.ebus.com
- electric, hybrid shuttle and rubber tire trolley buses

Lockheed Martin Control Systems
http://www.lmcontrolsystems.com/PowerDrive.htm
- HybriDrive™ system

New Flyer Industries
http://www.newflyer.com/alfu/alfudef.htm
- buses

North American Bus Industries
http://www.nabiusa.com
- buses

Nova BUS
http://www.novabus.com/prodindex-e.htm
- buses

Orion Bus Industries
http://www.transit-center.com/Orion
- buses

Advanced Vehicle Systems, Inc.
http://www.avsbus.com
- electric and hybrid buses

<u>Fuel Advocacy Groups</u>

Fleets & Fuels Newsletter
http://www.augustpacific.com
Fleets & Fuels Newsletter, covering alternative technology vehicles, is published by August Pacific.

Natural Gas (Compressed and Liquefied)

National Gas Vehicle Coalition
http://www.ngvc.org
This site contains general information and relevant legislation on natural gas vehicles.
Gas Research Institute
http://www.gri.org
This site contains publication and research being done in using natural gas as an alternative fuel.

Propane (LPG)

National Gas Association
http://www.propanegas.com/npga/
National Gas Association develops safety standards for the use of propane.

Alcohol Fuels

Methanol

American Methanol Institute
http://www.methanol.org/altfuel/index.html
This site provides updates and information on methanol being used as an alternative fuel.

Ethanol

American Coalition for Ethanol
http://www.ethanol.org
American Coalition for Ethanol provides a general description of ethanol and ethanol refueling sites in the United States.

Ethanol Information Center
http://www.greenfuels.org/ethindex.html
This site gives environmental information about using ethanol as an alternative fuel, such as emissions reduction.

Biodiesel

National Biodiesel Board
http://www.nbb.org
Information on biodiesel can be found at this site. Also, emission reduction information can be found.

Electric Drivetrain Vehicles

Defense Advanced Research Projects Agency (DARPA) electric vehicle projects
http://www.ev.hawaii.edu
This site is the general site for DARPA electric vehicle projects and connection to the seven consortia:
Electricore - not available at this time
NAVC – www.NAVC.org

SMUD - www.smud.org/evs/index.htm
SCAT- www.advtrans.org
MARCAV www.MARCAV.ctc.com
HEVDP- www.ev.hawaii.edu/HEVDP/HEVDP.html
Calstart – www.calstart.org
Electric Power Research Institute (EPRI)
http://www.epri.com
This site provides information for electric and hybrid vehicle projects.

Idaho National Engineering and Environmental Laboratory
http://spiderman.inel.gov/
This site shows results from INEL's hybrid and electric vehicle research. It also has links to recent publications concerning electric vehicles.

Electric Transit Vehicle Institute
http://etvi.org

Battery

Electric Vehicle Association of the Americas
http://www.evaa.org/vehicles/index.html
This site has responses to frequently asked questions about electric vehicles and a list of currently available electric vehicles.

EV World
http://www.evworld.com
Houses an online "library" of EV-related reports, articles, and news releases. Also sign up for a weekly EV newsletter.

Electric Vehicle News Magazine
http://evnews.net
A monthly publication "dedicated to the EV industry"; this site offers a calendar of conferences, information on AFV conferences, and an archive of past issues. Visitors can subscribe to the print edition.

Fuel Cell

Fuel Cells 2000
http://216.51.18.233/index_e.html
General information and technical updates about fuel cells are provided by Fuel Cells 2000.

Ballard Fuel Cells
http://www.ballard.com/products.asp
This site provides product information on fuel cells manufactured for transportation application.

Plug Power
http://www.plugpower.com
This site provides product information on fuel cells manufactured for transportation application.

Hybrid Electric

U.S. Department of Energy Hybrid Vehicle Propulsion Program
http://www.hev.doe.gov/
This site contains general information on hybrid electric vehicles and the U.S. Department of Energy Hybrid Vehicle Propulsion Program.

APPENDIX B

INTELLIGENT TRANSPORTATION SYSTEMS

1.0 INTRODUCTION AND OVERVIEW

Intelligent Transportation Systems (ITS) is a term used to describe projects which apply advanced technologies and communication systems to distribute and collect information to improve the efficiency and capacity of existing transportation systems. The growth and interest in ITS applications in the transportation industry have been significant in the past several years, as transportation system users and operators have an increased expectation for real-time systems information. The visitor experience and the comfort level with unfamiliar settings can be greatly enhanced with the provision of remote and on-site information about the transportation systems that the visitor may encounter. Appropriate and timely information can provide the visitor with the information necessary to successfully navigate to/from and within the natural environment of federal lands, including the following: parking, roadway systems, transit services, and trail systems.

This document first describes the functional areas of ITS as defined by *The Strategic Plan for IVHS [ITS] America*. Subsequently, this document focuses on the specific applications of ITS most relevant to group transportation systems found in or being considered for application on federally-managed lands. Section 3.0 discusses ITS vehicle technologies applicable to federal lands. Section 4.0 discusses ITS smart traveler technologies applicable to federal lands.

2.0 FUNCTIONAL AREAS OF INTELLIGENT TRANSPORTATION SYSTEMS

Several technologies are utilized in Intelligent Transportation Systems, including various types of computer hardware and software, and communication systems. Seven functional areas are briefly described below. Many of these functional areas apply the same technologies in different ways.

2.1 Advanced Traffic Management Systems (ATMS)

Advanced Traffic Management Systems are primarily aimed at improving vehicular flows on highways, arterial roads, and other streets. These systems typically use a combination of technologies that count, measure speed, and/or categorize motor vehicles to provide information to computers that control and adjust signal systems. Examples of this include the following:

- Traffic signals that adjust their timing to the flow of vehicles through an intersection,
- Freeway ramp metering systems that improve the flow of vehicles onto congested highways, and
- Speed detection and video surveillance of roadways that improves incident response.

2.2 Advanced Traveler Information Systems (ATIS)

Advanced Traveler Information Systems are aimed at providing users of the transportation system with more information with which to make decisions about route choices, estimate travel times, and avoid congestion. Most ATIS technologies are also aimed at the motor vehicle operator. Similar technologies, applied in a different way, are discussed below in reference to public transit. This broad category of applied technology includes the following:

- In-vehicle navigation systems (i.e. on-board computer maps) which can tell the drivers where they are and how to get to a destination,
- Variable message signs that provide information about congestion from traffic, and tell drivers which lanes to use or avoid, or provide alternate route information in case of road closures, and
- Terminals that could provide a color-coded network map showing congestion levels on area highways (a.k.a. congestion index).

2.3 Advanced Vehicle Control Systems (AVCS)

Advanced Vehicle Control Systems are aimed at increasing the safety and efficiency of vehicle operations. Using a combination of on-board computers and sensors and/or in-pavement markers, vehicles can be enhanced to do the following:

- Provide warnings to drivers to help drivers react to and avoid potential collisions.
- Initiate pre-crash restraint deployment of on-board vehicle systems.
- Operate on "autopilot," and reduce the spacing between vehicles on the highway while maintaining high safety levels.

With less spacing between vehicles, the facility capacity can be increased. Applied to other modes of travel, AVCS provides the capabilities to have fully-automated bus and tram shuttle systems.

2.5 Commercial Vehicle Operations (CVO)

ITS in commercial vehicle operations (trucking) applications applies Global Positioning Systems (GPS – uses satellites to locate vehicles) and other technologies primarily to increase the efficiency of freight movement and fleet management. Examples of this application include:

- Weigh-in-motion which allows trucks to transport and deliver goods, pay their share of roadway taxes, without needing to stop at a weigh station.
- Scanning technologies (lasers) are being used on roads and facilities with tolls to allow vehicles to pass through tollgates without stopping.
- GPS are used to locate and track the progress of deliveries.

2.6 Advanced Rural Transportation System (ARTS)

ARTS technologies provide information about remote road and other transportation systems. Examples include automated road and weather conditions reporting and directional information.

2.7 Advanced Public Transportation Systems (APTS)

APTS technologies can help improve transit and ridesharing services. By using GPS, wireless communication systems, and other devices, passengers are able to get more information about when a bus or carpool will arrive, know where a vehicle is along its route, and purchase a single card or pass that make transfers seamless and automatic. Operators and administrators of these systems are provided better quality information about who is using the services, when, and how.

3.0 ITS VEHICLE TECHNOLOGIES APPLICABLE TO FEDERALLY-MANAGED LANDS

This section focuses on the specific ITS applications most relevant to vehicles found in or being considered for application on federally-managed lands. The "smart vehicle" incorporates vehicle-based technologies to achieve more effective fleet scheduling and utilization.

The degree of technological sophistication needed to implement smart vehicle systems varies depending upon the type of service provided. Fixed route systems can function effectively in natural settings with minimal advanced technologies. Such technologies are currently in use in the public and private sectors.

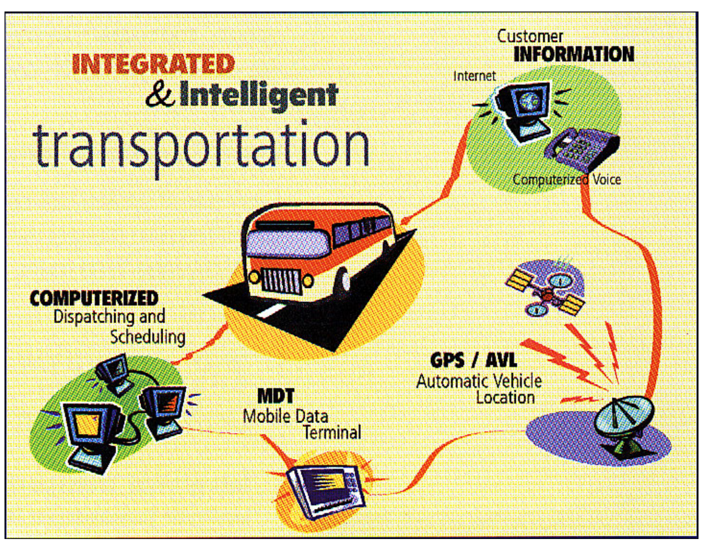
The following smart vehicle technologies are discussed in turn and their relationship is depicted in Figure B-1.

- Communication Systems.
- Annunciators (Talking Buses).
- Computerized Dispatching/Scheduling/Ridematching Systems.
- Automatic Passenger Counters.
- Automated Vehicle Location Systems.

3.1 Communications Systems

ITS communication systems for vehicles serve many purposes. Vehicles (buses) outfitted with the appropriate technology are able to communicate with traffic signals and gate mechanisms to receive priority over other vehicles or gain access to some roads restricted for use by transit vehicles only. Vehicle communication systems also include radio, cellular (wireless) phones, and location beacons. Two-way radios are used between a bus operator and a central dispatch system. Cellular phones sometimes provide more flexibility and require less centralization. On-board location beacons work with on board communication systems to provide other information about vehicles (see Automatic Vehicle Location section below)

Figure B-1: Relationship of ITS Technologies



3.2 Annunciators (Talking Vehicles)/In-Vehicle Information Displays

Annunciators provide verbal instructions and information to passengers on transit vehicles. As applied in automated systems such as airport people movers or on light rail systems, annunciators tell passengers which stop they are departing from and which stop they are approaching. In the natural settings of federally-managed lands, annunciators are being used to provide interpretation between stops in addition to helping passengers use the system itself. Annunciators are also used to provide comprehensive services for sight-impaired people and/or people unfamiliar with an area that may need to navigate by landmarks rather than street intersections.

In-vehicle information displays (see Figure B-2) function much the same way as annunciators, but provide visual cues and information rather than audio information. Often the two technologies are provided in tandem to maximize the visitor experience.

Figure B-2: In-Vehicle Information Displays

3.3 Computerized Dispatching/Scheduling/Ridematching Systems

Traditionally, scheduling software was used only for the preparation of driver assignments on specific routes and runs. It was done in advance with little ability to correct assignments on-demand. With the integration of ITS technologies, these computer systems are able to do the following:

- Make driver assignment and schedule changes on-demand and in real time,
- Accept data about actual performance versus expected performance and adjust scheduling,
- Accept advanced trip reservations for demand-responsive services.
- Assign trip requests to shared-ride vehicles with or without human intervention.

3.4 Automatic Passenger Counters

Automatic Passenger Counters (APC) provide automatic collection of passenger boarding and alighting information by bus stop or route segment by trip, time period, or day. Depending on the type of service, vehicle deployment strategy, and data needs, it might not be necessary to equip all revenue vehicles with APC technology. A number of transit systems equip only as many "data buses" as are required to survey the entire system by route or service sub-area over a period of time. APC technology offers the ability to collect accurate information concerning utilization of transit services and performs random trip sampling as required by Section 15 of the Federal Government Code. Often APC data is provided as input to the computer dispatching/scheduling/ridematching mentioned above. APC's can, but are not required to be compatible with smart card technologies. For more on smart cards, refer to Section 4.0.

3.5 Automatic Vehicle Location

Automatic Vehicle Location (AVL) Systems provide a dispatch center the capability to monitor the location of all vehicles continuously in real time. AVL is usually integrated with digital communications and Geographic Information System (GIS) mapping systems to streamline instructions from the dispatcher who is able to view vehicle itineraries and locations graphically. Each driver has a Mobile Data Terminal (MDT) in the vehicle that allows extensive planning information to be collected at a lower cost than by manual methods (i.e. schedule adherence, location-based passenger counts, and location-based fare collection information).

AVL technology has a significant positive effect on transit service quality, productivity, and customer satisfaction, including:

- Monitoring schedule adherence and minimizing the impacts of schedule delays on passengers.
- Coordinating passenger transfers between modes.
- Maximizing the productive use of capacity created by last minute cancellations, no-shows and unanticipated time savings in scheduled vehicle tours.

The equipment installed on-board each transit vehicle should consist of the MDT, a Vehicle Logic Unit (VLU) vehicle location sensor equipment and radio interface electronics and controls. In addition, a wide variety of additional devices could be interfaced to the AVL system via the VLU in the future. Some of the additional devices which the system design should be able to accommodate include silent emergency alarms, passenger counting equipment, engine monitoring and diagnostic equipment, door sensors, wheelchair lifts, fare boxes, traffic signal preemption devices, overhead sign control equipment and automatic audio and visual passenger information devices.

The VLU is the central processing and interface device on the transit vehicle. This device receives vehicle location data from the automatic location equipment and constantly compares the vehicle's location with the scheduled location. Any deviations beyond defined thresholds are indicated to the bus operator and reported back to the central dispatch system. The VLU is also responsible for recording data downloaded from the central dispatch system. The data recorded by the vehicle and uploaded to the system may be passed to other systems so that the data can be used to properly analyze the transit vehicle's operation and to improve the schedules and operational efficiency of the transit service.

These technologies are relatively mature and reliable for computerized scheduling and dispatching. A similar conclusion can be made for shuttle systems that are dominated by pre-ordered trips.

4.0 ITS SMART TRAVELER TECHNOLOGIES APPLICABLE TO FEDERALLY-MANAGED LANDS

This section focuses on the specific ITS applications most relevant to and usable by visitors in the natural settings of federally-managed lands. Smart traveler systems provide transportation system users with access to accurate, real-time information to make convenient travel decisions. Much of the technology necessary to support smart traveler systems is provided by the smart vehicle systems described earlier in Section 3.0.

Possible technologies that provide traveler information include:

- Web sites.
- Passenger Information Displays (Smart Kiosks).
- On-board Information Displays.
- Personal Wireless Devices.
- Automated Fare Collection (Smart Cards and Magnetic Strip Cards).

Figure B-3: Smart Kiosk

4.1 Websites

Computer-based web sites allow visitors (travelers) to get pre-trip information. Web sites are capable of providing static and real-time information. Static information includes such things as schedules, route maps, and system maps. Real-time information, depending on the sophistication of the system, could include information about the actual location or schedule adherence of a service compared to the static schedule, weather updates, and road or parking information.

4.2 Passenger Information Displays (Smart Kiosks)

Passenger information displays or (smart) kiosks (see Figure B-3) are the equivalent of a public website connection to transportation information. The advantage of the kiosk over the website is that the visitor to federal lands would not have to carry a computer with them to access the information. Kiosks can be placed at the entrance gate of federal land site or in each of that site's activity centers. For visitors arriving from outside the federal land site, similar kiosks can be stationed at nearby airports, in gateway communities, at regional visitor centers, and at state highway welcome centers.

4.3 Personal Wireless Devices

Personal wireless devices, including phones, internet access, the radio, pagers, and "palm pilot" type devices are all means of providing visitor information. Highway Advisory Radio (HAR) and other radio-based information sources have been in use in federal land sites for years. Communication capabilities are being increased such that it is now or will soon be possible to receive a page or a phone call from the bus to inform the visitor/passenger that that service will be arriving within several minutes.

In connection with the GPS and AVL systems mentioned in the previous section, information can also be transmitted to fixed signs. Signs placed in terminals or at bus stops can then display real-time information for passengers.

4.4 Automated Fare Collection (Smart Cards and Magnetic Strip Cards)

A smart card is a highly tamper-resistant chip and an integral operating system. The operating system provides the commands, data access, and security controls. The smart card must be inserted in a reader/writer machine that supplies power to the chip and the connection for communication. The card is reusable but expensive. Magnetic strip cards are a less expensive option, and provide some (but not all) of the same benefits as smart cards, including storing monetary (fare) information. Magnetic strip technology is available in disposable paper form as well.

In transit applications, smart cards combine secure, cash-less transactions and personalized applications. These also provide transit authorities with the demographic information needed to meet government reporting requirements and to market to target groups. In the transit environment, smart cards can be used as debit, credit or stored-value cards. For the natural settings of federal lands, these cards could provide a convenient means of fare payment for patrons using on-site transit service repeatedly over a period of several days. Ultimately, the use of the cards could be integrated into payment systems for other services.

5.0 SUMMARY AND CONCLUSIONS

Collectively, as ITS technologies are more fully integrated into the federal land setting, they will provide information on the status of a transportation system and will be useful in managing an entire transportation system (all modes) in a manner not previously possible. ITS technologies will increase both the quantity and quality of information, as well as provide the ability to respond to transportation system dynamics in a real-time fashion. Such ITS technologies will allow federal land managers and visitors to take advantage of opportunities (surplus capacity) and respond to problems (congestion, incidents, etc.) as they happen. It will allow federal land sites to better adjust other visitor management tools (ticketing, fees, etc.) and services (interpretation, concessions, etc.) congruent with the transportation system performance. It will also allow federal lands to provide additional travel/tour information at a distance to visitors arriving from gateway communities (especially rural locations), nearby airports or bus terminals, and other facilities.

REFERENCES

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Euler, Gary W. and H. Douglas Robertson, Eds. National ITS Program Plan. Synopsis, Volume I, and Volume II. ITS America and U.S. Department of Transportation. March 1995.

Kikuchi, Shinya Ph.D., Sandeep Aneja, Partha Chakroborty, Anthony J. Hofmann, Motoya Machida, and Vijaykumar Perincherry. Advanced Traveler Aid Systems for Public Transportation. U.S. Department of Transportation and. September 1994.

Schweiger, Carol L., Mary Kihl, and Larwrence Labell. Advanced Public Transportation Systems: The State of the Art, Update '94. U.S. Department of Transportation and Federal Transit Administration. January 1994.

The Strategic Plan for Intelligent Vehicle-Highway Systems in the United States. Intelligent Transportation Society of America. May, 1992.

APPENDIX C

LIST OF VEHICLE MANUFACTURERS BY VEHICLE TECHNOLOGY CATEGORY

This appendix provides a list of manufacturers by vehicle technology category, along with their web site if available. This list was compiled during the research for this report. This list is a helpful starting point for further research into the vehicles of particular manufacturers. This list does not necessarily identify every manufacturer for each vehicle technology.

List of Vehicle Manufacturers

Bus / Rubber Tired Transit

Company Name	Website or Other Contact
ABC Bus Companies, Inc.	**Www.abc-bus.com**
Arrow Line, Inc. (A Coach USA Company)	Www.arrowline.com
Autobus	Www.icenet.it/basco
Bluebird	Www.blue-bird.com
Breda Transportation, Inc.	Pistoia, Italy
Chance	Www.chancecoach.com
Champion Bus, Inc	**Www.championbus.com**
Collins (Midbus)	**Www.collinsbus.com**
Designline	**Www.designline.co.nz**
Double Decker Bus Company	Www.doubledeckerbus.com
DuponTrolley Industries	Www.dupontrolley.com
Ebus, Inc.	Www.ebus.com
El Dorado	**Www.econoline.com**
Electric Transit Inc. (ETI)	**Www.electrictrolley.com**
Girardin	Www.girardin.com
Gillig	Www.gillig.com
GLAVAL Corporation	Www.glavalbus.com
GMC	Www.gmc.com
Greater Indianapolis Transportation Inc. (Goshen Coach)	**Www.grtrindytrans.com**
HICOM Carriage Engineering	**Www.plexus.net/buses**
Hino Diesel Trucks (USA), Inc.	**Www.hinotruckusa.com**
International	**Www.navistar.com**
Krystal Koach Inc.	**Www.krystalkoach.com**
Marcopolo	Www.marcopolo.com.br
MASA	**Www.masa.web.com.mx/catmsae.html**
MCI	**Www.mbnet.mb.ca/motori**
Metro-Trans	**Www.metro-trans-corp.com**
Mobile Seats	**Www.mobileseats.com**
NABI	**Www.nabiusa.com**
Neoplan USA Corporation	**Www.neoplan.de**
New Flyer of America Inc.	Www.newflyer.com
Nextbus	**Www.nextbus.com**
North American Bus Industries	**Www.nabibus.com**
Novabus	**Www.novabuses.com**
Orion Bus Industries	Mississauga, Ontario
Scania	**Www.scania.se**
Setra	**Www.setra-coaches.com**
Sitcar	**Www.sitcar.com**
Specialty Vehicles	Www.specialtyvehicles.com
Sydney Buses	Www.sydneybuses.nsw.gov.au
Thomas Built Buses	Www.thomasbus.com
Transtar – The Bus Company	**Www.tran-star.com**
Transteq	Denver, Colorado
Trolley Enterprises	**Www.trolleyent.com**
VOLVO Buses	**Www.bus.volvo.se**
Western Star Trucks Holdings Ltd.	**Www.westernstarholdings.com**
World Bus Company	Www.worldbuscompany.com
World Trans, Inc.	Www.wtrans.com

Rail / Guided Transit

Company Name	Website or Other Contact
Aerobus	**Www.aerobus.com**
Aeromovel	**Www.aeromovel.com**
Aerorail	**Www.aerorail.com**
Adtranz	**Www.adtranz.com**
Alstom	**Www.alstom.com**
Bombardier	Www.bombardier.com
Construcciones y Auxilrar	Madrid, Spain
Breda Transportation, Inc.	Pistoia, Italy
Doppelmayr	**Www.doppelmayr.com**
Fiat	Www.fiat.com
FUTREX (in conjunction w/Battelle)	Www.batelle.org
General Motors Electro-Motive Division	Www.gmemd.com
Hitachi Ltd.	Www.hitachi.co.jp
Pomagroup	**Www.pomagroup.com**
Siemens	Www.usa.siemens.com

High Gradient Transit

Company Name	Website or Other Contact
Alstom	**Www.alstom.com**
Bombardier	Www.bombardier.com
CWA Construction	**Www.cwa.ch**
Doppelmayr	**Www.doppelmayr.com**
Garaventa	**Www.garaventa.com**
Pomagroup	**Www.pomagroup.com**

Waterborne Transit

Company Name	Website or Other Contact
Advanced Multihull Designs (AMD)	**Www.amd.com.au**
ALMAZ	**Www.almaz.com**
Bale Engineering Co. Pty. Ltd.	**Www.midcoast.com.au**
Boulat	**Www.boulat.com**
Conoship International	**Www.conoship.com**
Gladdding-Hearn Shipbuilding	**Www.gladding-hearn.com**
Volga Shipbuilding	**Www.plugcom.ru**

Group Snow Transit

Company Name	Website or Other Contact
Foremost Industries, Inc.	**Www.foremost.ca**
Prinoth	**Www.prinoth.com**